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THE ECONOMICS OF INDUSTRIAL WATER USE IN ALBERTA: QUANTITATIVE AND QUALITATIVE ASSESSMENT

by

© JOHN L. KNAPP

A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled The Economics of Industrial Water Use in Alberta: Quantitative and Qualitative Assessment submitted by John L. Knapp in partial fulfilment of the requirements for the degree of Master of Arts

ABSTRACT

The economics of industrial water use in Alberta is the focus of this thesis. Attention is given to both the quantitative and qualitative aspects of industrial water use. The analysis is based primarily on data collected by an industrial water use survey conducted in early 1973.

Analysis regarding the quantitative characteristics of industrial water use in Alberta focuses on four separate but interrelated themes. The first is an examination of the current water use pattern of the industrial sector in Alberta. The Oil Extraction Industry is found to be the largest consumptive user of water. All water for this use is provided privately, the source being primarily surface water. The second theme is concerned with the relationship of current industrial water demand to existing supplies of water. No real conflict is apparent on a provincial basis, although water shortage with respect to specific seasons or basins may be a potential concern.

A third theme regarding the quantitative characteristics of industrial water use in Alberta centers on the estimation of future levels of industrial water

demand. It is assumed that the price of water has only minor effects on the quantity demanded; future levels of this demand are therefore assumed to be fixed to the level of output. The fourth aspect of industrial water use in Alberta --the relationship of available supplies to the anticipated level of industrial and total demand--would imply that there is little evidence to suggest future water shortages for this use although the South Saskatchewan River basin could realize some problems. However, if pressure were to be realized on water supplies, institutional flexibility (through the water rights system) is felt to be the key to the allocative problem along with water storage and diversion schemes.

The qualitative characteristics of industrial water demand is examined. The Food and Beverage Industry has the greatest potentially deleterious waste water discharge based on BOD. Secondly, alternative policies regarding water quality management are studied with respect to their applicability to Alberta. Thirdly, it is recommended that an examination regarding the implementation of a water quality management system based on effluent charges be undertaken.

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CHAPTER I

Introduction

Nature and Scope of the Study

This thesis is an examination of the economics of industrial water use in Alberta. It is focused on theoretical and policy analyses relating to the quantitative and qualitative aspects of this use. The analysis is based primarily on an industrial water use survey which was conducted in Alberta during the spring of 1973. Much of the thesis is an examination of the results of this survey. An attempt is made in this study to derive a demand model which could be utilized for estimating future water requirements for the industrial sector in the province. The influence of price on the demand for water is examined along with discussion regarding the possible impact of industrial activity on water quality. Alternative abatement policies are reviewed and recommendations made with respect to possible water quality policy innovations for Alberta. Areas of future research possibilities are also outlined.

Industrial activity in Alberta has increased considerably in the past few years. A measure of such activity is the nominal value of production which has, in

the manufacturing sector, increased from about 1.1 billion dollars in 1963 to nearly 2.5 billion dollars in 1970. Accompanying this increased industrial activity has been an increase in the quantity of water required by industry from about 106 thousand acre feet to about 253 thousand acre feet for the corresponding period. This latter quantity of water is about 15 per cent of the total amount of water withdrawn by all users in Alberta with the exclusion of that for hydroelectric purposes. Although it would appear that the demand for water by industry is small relative to other uses in Alberta, the geographic and temporal distribution of this use, together with water quality implications, could well be significant.

A further consideration regarding industrial water demand is whether or not there are in fact sufficient quantities of water available to meet current and anticipated requirements. In order to analyse this situation, the supply-demand relationships are examined on a river basin basis. The five major river basins in Alberta are illustrated in Figure 1.

Water, in general, is considered a common property resource. As such, it is often the responsibility of public authorities to monitor its use. To the extent that the use of this resource must be monitored, policies based on sound

TOPOGRAPHY AND RIVER BASINS OF ALBERTA

Prepared for Water Resources Division, Department of the Environment, by Surveys Branch, Department of Highways and Transport, Edmonton, Alberta.

information must be formulated. Since the industrial sector is one such user of water in Alberta, the extent and implications of this use must be determined along with those of all other uses in order that enlightened policy decisions be made regarding the utilization of this resource. The major policy concerns in Alberta relative to the industrial use of water emphasize both the quantitative and qualitative issues. The adequacy and flexibility of present legislation in dealing with these issues in Alberta, now and in the future is of special policy importance and is, therefore, a major concern of this thesis.

Objectives

The overall objective of this thesis is to examine the relevant policy issues in Alberta regarding industrial water use. It would appear that conceptually there are two distinct but interrelated themes regarding this subject; one such theme emphasises the quantitative nature of industrial water use while the other is concerned with the quality side.

The objective regarding the quantitative aspect of industrial water demand implies certain sub-objectives. The first of these is to examine the current water demand pattern of the industrial sector with reference to specific industries and geographic locations. Once these

characteristics have been established, it is necessary to relate these demands to existing water supplies. This is a second sub-objective. The third such objective involves the estimation of a demand function for industrial water in Alberta. Examination of potential explanatory variables is undertaken. Once a satisfactory projection model is derived, anticipated future demands are estimated. The final sub-objective on the quantitative side of industrial water demand is to relate these anticipated levels of industrial (and total) water demand to existing supplies.

The examination of the qualitative aspect involved in the water use of the industrial sector in Alberta also has a number of sub-objectives. The first of these is to establish which industry discharges the greatest volume of waste-water and to relate this geographically. The volume of discharge implies little about the quality of the effluent; therefore, the quality of effluent resulting from industrial activity is also discussed. A second sub-objective regarding the qualitative aspect of industrial water demand in Alberta involves an examination of current and proposed policies designed to control or eliminate water quality deterioration resulting from industrial activity. The policy which economists would tend to favor - effluent charges - is given special consideration. The final sub-objective is to suggest improvements in the present water quality policies in

Alberta where inadequacies are revealed.

Definition of Terms

There are numerous overlapping and confusing expressions in the literature which refer to industrial water utilization.[1] Terms such as water use, water requirements, water demand, water withdrawals, water intake, and consumptive use of water are often used interchangeably. The term water demand is often used to imply specific physical quantities of water needed. Such usage obscures the economic implication associated with the therm 'demand'. Bower concludes that the "demand for water is similar to the demand for any factor input to an industrial production process. . . Water intake is equivalent to the economic concept of water demand. It is not a fixed, immutable figure, but is meaningful only in relation to a number of factors".[2] The role which water plays in the industrial productive process could be presented as in Figure 2.[3]

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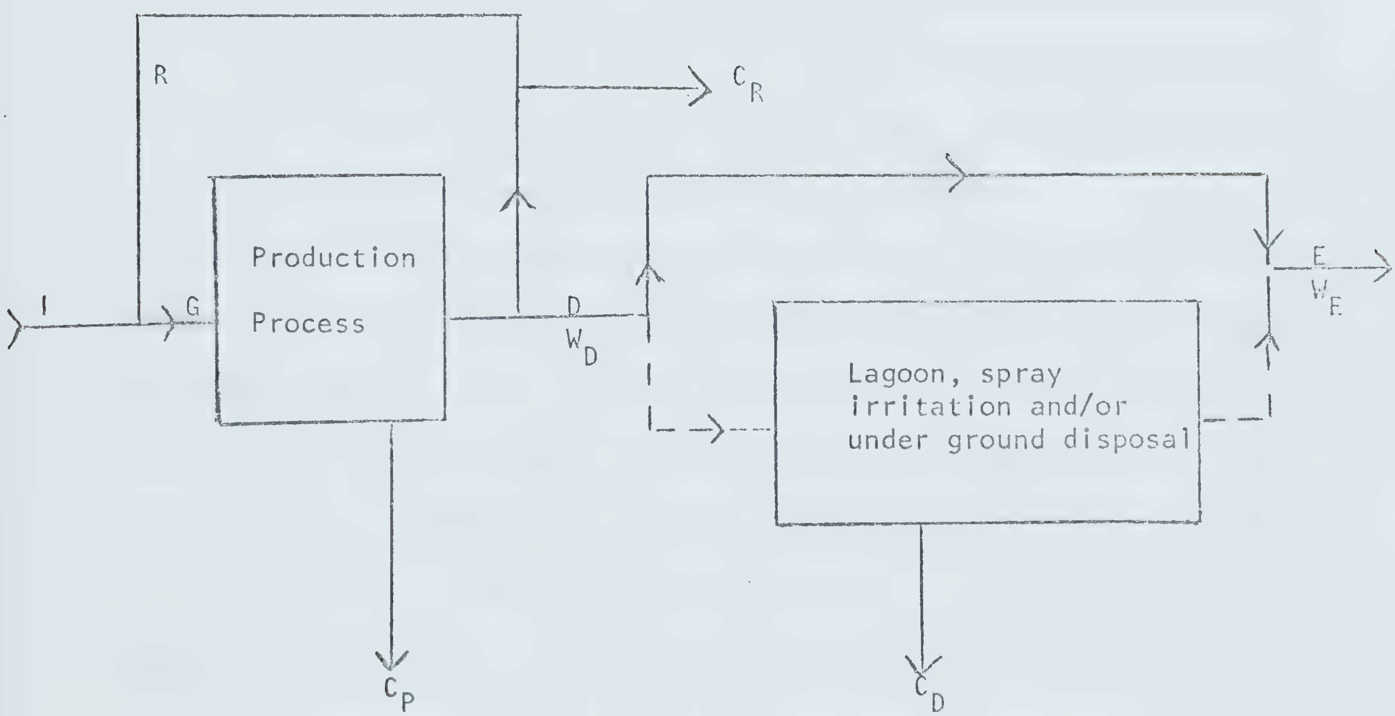
1. This section is based on: B. Bower, "Economics of Industrial Water Utilization" Water Research ed. A. Kneese and S. Smith (Baltimore: John Hopkins Press, 1966).
2. Ibid., pp. 166-167.
3. Ibid., p. 147.

Figure 2

The Role of Water in
The Productive Process



In Figure 2:

I = Intake Water
R = Recirculated Water.
G = Gross applied for all in-plant uses.
D = Waste water discharge from the productive process.
C = Consumptive use or net depletion of water = I - D or C + C + C where C = consumptive use in the production process, C = consumptive use in the waste water disposal system, and C = consumptive use in the recirculation process.
E = Final effluent from the production unit (available for reuse). Where a lagoon or spray irrigation system is involved, it consists of lagoon outflow seepage, and/or surface runoff, if any.
W_E = Waste load in the final effluent, pounds of BOD.
W_D = Waste load in the waste water discharge, for example, pounds of BOD.
Degree of recirculation = R/Gx100.

The degree of recirculation is essentially the share of the gross water applied that is procured from recirculated water and may have a value ranging from zero to slightly less than 100 per cent. Therefore, as used in this thesis the terms referring to industrial water demand imply water entering the productive process as intake water.

Tools of Analysis

A major input into this thesis is the industrial water use survey conducted in early 1973 under the auspices of the Alberta Department of the Environment.[4] Two types of

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4. See Appendices III and IV and Chapter II for further information on the survey.

questionnaire were used. One had a very generalized format asking the entrepreneur to state the quantity of water intake for his firm in 1972. This questionnaire was sent to small water users. The other questionnaire was more detailed in the sense that it solicited information regarding the source, use, recirculation, and treatment of the water used by each respective large water demanding firm. The results of this survey are presented in Appendix VIII and discussed throughout the thesis. In order to present the results of the survey, on a micro level, the industrial sector of the province was disaggregated according to the latest Standard Industrial Classification (see Appendix I). The results are presented at the Division (one-digit) level, the Major Group (two-digit) level, and in some cases the Subgroup (three-digit) level.

Another tool employed in this thesis is the least squares regression technique. This tool is used to estimate, over time, the relationship between water demand in physical terms (dependent variable) by the respective industries and the real value of production (independent variable). The study period is 1968 to 1972 inclusively. The value of production figures are deflated to constant (1961) dollars for comparative purposes. The result of the regression analysis is that an estimated demand function for water by industry is derived. The slope coeficient is essentially the

marginal water coefficient (additional acre-feet of water required per additional thousand dollars of production) which is compared with the average water coefficient. The purpose of this comparison is to determine if, in fact, the quantity of water required per unit of output is increasing or decreasing over time, implying water-using or water-saving technological changes respectively.

Data

The data base for this study is essentially primary in nature. Information regarding the water demand pattern of the industrial sector in Alberta was obtained from the survey recently conducted by the Department of Environment. Secondary data are used in the derivation of the water coefficients,[5] as well as in the discussion of the water quality implications resulting from activity in the industrial sector in Alberta.[6]

Limitations

There are a number of constraints under which this thesis is written. One of these is the possible inaccuracy of the results of the survey. Any research which is based on

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5. Dominion Bureau of Statistics, Manufacturing Industries of Canada: Prairie Provinces, 1963 to 1970.
6. Alberta Department of Environment, An Inventory of Water Pollutant Emissions in the Province of Alberta, 1970 - 1972, March, 1973.

primary data is constrained by potential inaccuracies in the data. Another limitation is the result of the necessary level of aggregation. For example, this research would have been enhanced if it had been possible to obtain value of production data for each individual firm. This would have improved the results of the regression analysis. However, aggregation to the two-digit level was necessary due to rules of confidentiality and thus severely hampered the derivation of usable marginal water coefficients.

In spite of the above difficulties and the apparent insignificance of industrial water demand relative to total water demand, study of industrial water demand in Alberta is relevant. This thesis is focused on the key issues surrounding industrial water demand in this province and as such is designed to enable the water resource planner to make more enlightened policy decisions in the future. It is a first approximation; much further research is required.

Format

The format of this thesis basically follows the sequence outlined in the discussion regarding objectives. Chapter II is a summary of the results of the industrial water use survey. Chapter III first examines current levels of industrial (and total) water use relative to existing supplies and, secondly, attempts to derive a demand model

and project the requirements for water by the industrial sector in Alberta to 1980. These anticipated demands, along with those of all other water users in the province, are related to existing supplies. Chapter IV discusses the water quality implications of industrial activity in Alberta, while Chapter V summarizes the study and puts forward suggestions for policy changes, as well as potential areas of future research pertinent to industrial water issues in Alberta.

Chapter II

Survey Results and Analysis

General

The survey upon which this thesis is based originated with the Alberta Department of the Environment. The purpose of the survey was to update existing information regarding water use by the industrial sector in order that more enlightened policy decisions could be made in this area. To this end, a questionnaire system was designed to glean the necessary information from the industries themselves regarding their use of water.

All industries in the province are categorized according to the most recent Standard Industrial Classification Code. The complete coding system is displayed in Appendix I. This thesis is concerned only with those firms engaged in mining and manufacturing. These firms encompass the overwhelming bulk of industrial activity in Alberta.

As stated above, a questionnaire system was used to obtain data regarding industrial water use in Alberta. This system was supported by a letter drafted by the Minister of

the Environment (See Appendix II). Two types of questionnaires were used. One questionnaire, found in Appendix III, was designed for use by known small water users and simply solicited information with respect to the range of gallons the respective firms used in 1972. The purpose of this generalized questionnaire was to ensure that even the users of insignificant volumes of water were included in the study. In the case where a firm receiving this questionnaire withdrew more than one million gallons of water in 1972, that firm was given a larger, more detailed questionnaire.

The detailed questionnaire, presented in Appendix IV, was sent to establishments which were considered to be large users of water based on a similar survey conducted in 1967. This latter survey was found to be incomplete due to poor response. It did, however, provide a basis for the design of the current one with which this study is concerned, and led to the formulation of the detailed questionnaire.

The latter questionnaire was designed in such a way that information regarding not only intake volumes but the source, use, extent of recirculation, treatment, and volume of discharge was forthcoming. In the event that a firm failed to or was unable to provide the required information, three alternatives were available. Firstly, if the

establishment obtained water from some municipal system, the latter was generally able tc supply at least the data on the volume of intake. Secondly, if data were available from the 1967 survey, they were used, and thirdly, where either of the first two alternatives did not apply, it was assumed that the water use patterns for such firms were not unlike those of the same industry for which data were available, and information was imputed on this basis. It must be pointed out, however, that in the case of the larger questionnaire, 90 per cent of those sent out were returned and usable; for the smaller questionnaire, the usable portion was approximately 63 per cent. This means that data were obtained from secondary sources or imputed in only 10 percent and 37 per cent of the cases respectively. Data regarding water use by the crude oil industry were obtained from secondary sources[1]. These data are published up to 1971 and pertain to activity at the "field" level rather than for individual wells. Therefore, the data presented in subsequent sections is that for <u>all</u> firms in the respective industries and should present the total picture of industrial water use in Alberta.

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1. Energy Resources Conservation Board. "Summary of Monthly Statistics" Calgary. 1972

Location of Water-Using Industries in Alberta.

Industrial activity of the sort with which this study is concerned is spread almost entirely throughtout the province. Each firm was coded with respect to its geographic location along with data pertaining to its water use pattern. Table 1 shows the distribution of firms in both the Mining and Manufacturing Divisions as it occurs on an urban basis. The geographic arrangement of two- and three-digit industries is presented in Tables VIII-1 to VIII-6.

TABLE 1

Industrial Location: Seven
Urban Centers, Other:
Alberta, 1972
(number of Firms)

	Division		
Location	Mines, etc.	Manufacturing	Total
Edmonton	3	100	103
Calgary	10	102	112
Lethbridge		35	35
Medicine Hat		19	19
Grande Prairie	1	12	13
Peace River		2	2
Red Deer		20	20
Other	138	93	231
TOTAL	152	383	535

From Table 1 it is apparent that most of the industrial activity in terms of the numbers of firms occurs in urban centers. This should imply that most of the water used by industry in Alberta is supplied by municipal systems. However, before one can arrive at such a conclusion, the amount of water used per firm must be known; then one can address the subject of private versus public supply of water for industry in the province. This is done in a later section. It should be mentioned here that "other" in Table 1 refers to firms in other urban centers as well as rural areas in Alberta.

Water resource planners are interested not only in industrial water use in punctiform space, but also on a more aggregative regional basis. For this reason, data are presented on a river basin basis. Table 2 reveals the distribution of industry as it occurs in the five major river basins in Alberta for the two divisions.

Table 2 reveals that the firms in the Mines Division are distributed quite evenly among the five river basins while the same is not true for the Manufacturing Division. The North and South Saskatchewan River basins appear to support the majority of the manufacturing activity in the province. One can observe from Table 1 that the large urban

TABLE 2

Industrial Location: Five River Basins, Alberta, 1972 (number of firms)

River Basin	Division: Mines, etc	Manufacturing	Total
Peace	18	20	38
Athabasca	27	2	29
North Saskatchewan	35	140	175
Red Deer	31	31	62
South Saskatchewan	41	190	231
TOTAL	152	383	535

centers in the two respective basins influence this distribution. That is, Calgary, Lethbridge, and Medicine Hat account collectively for 119 out of the total 137 firms in the South Saskatchewan River basin while Edmonton in the North Saskatchewan River basin houses 82 of the 107 firms. The balance of firms in these river basins are located in smaller urban centers and in the surrounding hinterland.

Industrial Water Intake

Industries operating in Alberta during 1972 collectively had an intake of approximately 270 thousand acre-feet. Table 3 shows the distribution of water intake by the major two-digit industries. For a complete tabulation of

all two- and three-digit industries and their water intake, see Tables VIII-7 to VIII-12.

TABLE 3

Water Intake By
Major Two-Digit Industries:
Alberta, 1972
('000 acre-feet)[1]

Industry	Intake	% of Total Intake
Mineral Fuels	101	37
Chemical	71	26
Petroleum and Coal	33	12
Paper	31	11
Food and Beverage	22	9
Others	12	5
TOTAL	270	100

From Table 3 it appears that the industry with the largest volume of water intake in 1972 was Mineral Fuels. It should be noted here that the Petroleum Industry contains those firms engaged in petroleum refining while those in Mineral Fuels Industry extract the raw product from the earth. The Mineral Fuels group has been disaggregated into its component three-digit subgroups. These are shown in

---

1. 1 acre-foot = 271,335 Imperial gallons.

Table 4.

TABLE 4

Water Intake By Mineral Fuel
Three-Digit Industries:
Alberta, 1972
('000 acre-feet)

Industry	Intake	% of Total Intake
Coal	2	2
Natural Gas	42	41
Oil	57	57
TOTAL	101	100

The location of firms dictates to a large extent their source of intake water. Essentially all establishments in the Mineral Fuels group are located in rural areas implying a self-supply system of water. For this group, nearly all water is obtained from surface sources. About half of this water is taken from the Athabasca River basin while about one quarter is obtained from the North Saskatchewan River basin. Most of water used in the Oil Extraction subset of this group is drawn from the latter basin.

Nearly all the water withdrawn by the Chemical Industry is taken from the South Saskatchewan River basin. However,

an interesting phenomenon presents itself. Although nearly all the firms in this industry are located in urban centers, they obtain only about 4 per cent of their water from the respective municipal systems. Most of the water intake by this group occurs in Calgary, the major source being private ground water systems.

As with the Chemical Industry, most of the intake water for the Petroleum Industry is from the South Saskatchewan River basin. Also, most of the water taken into the various plants has as its source surface water even though most firms are located in the urban centres. Although there are more Petroleum and Chemical firms in Edmonton then Calgary vast water withdrawls of two firms in the latter city account for apparent discrepancy.

Firms in the Paper and Allied Industries are located almost exclusively in the Athabasca River basin. They are established in primarily non-urban areas and obtain nearly all of their intake water from surface sources.

The Food and Beverage Industry is second largest in terms of the number of firms (the Mineral Fuels Industry is first) but is fifth according to water intake. The South Saskatchewan River basin appears to contain the majority of firms engaged in production of this type. Firms in this region account for nearly 70 per cent of the intake water

for the industry. Over 60 per cent of the water for this industry is provided by municipal systems.

Table 2 presented the distribution of industries on a river basin basis. Since water intake varies considerably among industries, it is interesting to note the distribution of the quantities of industrial water intake based on river basins. Table 5 is such a presentation. Water intake by individual industries according to river basins is shown in Tables VIII-10 and VIII-12.

TABLE 5

Industrial Water Intake:
Five River Basins
Alberta, 1972
('000 acre-feet)

River Basin	Intake	% of Total Intake
Peace	11	4
Athabasca	78	29
North Saskatchewan	68	25
Red Deer	8	3
South Saskatchewan	105	39
TOTAL	270	100

From Table 5 it would appear that the South Saskatchewan, Athabasca, and North Saskatchewan River basins respectively are the 'important' ones based on industrial

water intake. This order differs significantly from that of Table 2 based simply on the numbers of firms.

The source of the industrial water supply is important to clarify. This is attempted in Table 6 which shows, again on a river basin basis, the quantity of water taken from surface, ground, and municipal sources respectively. These data are disaggregated by industry and presented in Tables VIII-13 to VIII-18.

TABLE 6

Industrial Water Intake
By Source: Fine River Basins.
Alberta, 1972.
('000 acre-feet)

	Water Source			
River Basin	Surface	Ground	Municipal	Total
Peace	8	3	1	12
Athabasca	71	1	5	77
North Saskatchewan	48	5	12	65
Red Deer	5	2	1	8
South Saskatchewan	37	54	14	105
TOTAL	169	65	33	267

The total values in Table 6 do not match those of Table 5 due to rounding; however, Table 6 does reveal that only 12 per cent of all water intake by industry in Alberta is

supplied through public systems. The remaining 88 per cent is provided privately; these are essentially pumping systems which take water from either surface or underground sources and make it available to the productive process. The firm must therefore bear all the costs of acquiring water in such cases.

The firms presented in Table 3 as being the ones with largest water withdrawals in Alberta during 1972 accounted collectively for 95 per cent of all industrial water intake. It would be interesting at this point to note those firms which experience the highest degree of recirculation.

Industrial Water Recirculation

In 1972, industries in Alberta recirculated a volume of water slightly greater than one million acre-feet. This would imply that, across all industries, each acre-foot drawn into the plant was, on the average, recirculated four times before being discharged. However, not all industries recirculate water to the same extent. Those two-digit industries which accounted for the majority of recirculation are shown in Table 7.

It is interesting to note the ranking of the important water recirculating industries relative to that of water intake. The Mineral Fuels and Chemical industries maintain

TABLE 7

Water Recirculation By
Major Two-Digit Industries
Alberta, 1972
('000 acre-feet)

Industry	Recirculation	% of Total Recirculation
Mineral Fuels	479	46
Chemical	352	34
Primary Metals	104	10
Petroleum and Coal	62	6
Food & Beverages	31	2
Paper	8	1
Other	7	1
TOTAL	1043	100

their position, but the Primary Metal industry with an intake of only 45 hundred acre-feet surpasses the Petroleum and Coal Industry in terms of water recirculation. Also note that the Paper and Allied Industries and the Food and Beverage Industry switch positions in the rank of water recirculating industries. It would appear, however, that there is some relationship between the volumes of water withdrawn and recirculated by industry. Complete data regarding the amount of water recirculated by all two- and three- digit industries in Alberta during 1972 are presented in Tables VIII-19 to VIII-22.

Since the amount of recirculation varies from industry to industry and even from plant to plant, so does the relationship between the volume recirculated and the gross water applied to the productive process. Recall that gross water applied was defined as the summation of the intake and recirculated quantities of water. That proportion of gross water applied that is obtained by recirculation is given by the degree of recirculation. This value is usually expressed as a percentage. Approximately 80 per cent of the gross water applied by all industries is obtained from recirculation. Table 8 shows those two-digit industries having the highest degree of recirculation. This information for all industries is displayed in Tables VIII-23 to VIII-26.

It would appear from Table 8 that there is no close relationship between either the volume of intake or recirculation and the degree of recirculation in terms of the ranking of the top two-digit water-using industries.

Locationally, most of the recirculation of water takes place in the North Saskatchewan River basin. This is due primarily to the large volume of water (301 acre-feet) that is recirculated in the Chemical Industry in that region. Although the Mineral Fuels Industry recirculates the most

TABLE 8

Two-Digit Industries Having
The Highest Degree of Water
Recirculation:
Alberta, 1972
(per cent)

Industry	Degree of Recirculation
Primary Meals	96
Metal Fabricating	94
Wood	85
Chemicals	83
Mineral Fuels	83
Petroleum and Coal	65
Food and Beverages	58

process water, it takes place on an evenly distributed basis across the province. The city which experiences the greatest amount of recirculation is Edmonton, due again to the existence of the Chemical Industry.

The geographic distribution of the degree of recirculation is also interesting. On a river basin basis, industries in the Red Deer River basin have the highest degree of recirculation. The existance of nearly one-quarter of the firms engaged in Mineral Fuel extraction in this basin and the fairly high degree of recirculation in this group contribute significantly to this fact. In terms of

urban centers, industries located in Edmonton have collectively the highest degree of recirculation, followed by those in the city of Medicine Hat.

After water has passed through the industrial productive process it is discharged. One would hypothesise that the volume of water discharged from a plant would be closely related to the volume of intake. If this hypothesis does not hold and the industrial heirarchy based on the volume of water discharged is different from that established by the intake volume, then one would have to analyze the consumptive use patterns of the relevant industries. This is undertaken in a further section. The first step is an examination of the water discharge pattern for industry in the province.

Water Discharge by the Industrial Sector in Alberta

In 1972, nearly 175 thousand acre-feet of waste water were discharged by industry in Alberta. Table 9 shows which two-digit industries accounted for the majority of this discharge. Waste water discharge data for all industries are given in Tables VIII-27 to VIII-30.

It is of interest to note in Table 9 the ranking of industries on the basis of waste water discharge. Except for the Mineral Fuels Industry, all others have their same

TABLE 9

Two-Digit Industries Having
the Greatest Waste Water
Discharge Volumes
Alberta, 1972
('000 acre-feet)

Industry	Discharge	% of Total Discharge
Chemical	66	38
Petroleum and Coal	31	18
Paper	27	15
Mineral Fuels	24	14
Food and Beverages	21	12
Other	6	3
TOTAL	175	100

relative position as in Table 3 based on intake volume. For nearly all industries in Table 9, the quantity of waste water discharge is greater than 90 per cent of the volume of intake. The Mineral Fuels Industry is an exception mainly due to the near zero discharge in the Oil Extraction subset of this group. For the Mineral Fuels Industry, the volume discharged is only 24 per cent of that withdrawn. This implies that the latter industry is a large consumptive user of water; reasons for this will be made explicit in a further section.

The geographic distribution of waste water discharge follows fairly closely that of intake. On a river basin basis, the South Saskatchewan River basin receives most of the waste water discharge, and that mainly from the Chemical Industry. The Athabasca River basin accepts the next largest volume of discharge, attributable to the Paper and Allied Industries group. The Chemical Industry based in Calgary contributes to that city having the largest volume of industrial waste water discharge of any city in the province.

Industrial Waste Water Treatment

That industries today must be conscious of public sentiment regarding water pollution is apparent. To the extent that industries are responsive to these feelings, the treatment of waste water is conducted. Government legislation sets down limits regarding the content of sewage effluent and has, via the Clean Water Act, the power to stop the operation of any plant not functioning within these guidelines.

Approximately 40 per cent of the waste water was treated, either chemically or otherwise, to improve its condition before being discharged from the respective plants in 1972 in Alberta. Some of the remaining 60 per cent

receives municipal treatment. The Paper and Allied Industries group collectively treated the most sewage. For this group, approximately 26 thousand acre-feet of discharge were treated, amounting tc nearly 97 per cent of total waste water discharged by that group. Table 10 displays the major two-digit industries in terms of waste water treatment. These data for all two- and three-digit industries are shown in Tables VIII-31 to VIII-34.

TABLE 10

Two-Digit Industries Treating
The Greatest Volumes of
Waste-Water
Alberta, 1972
('000 acre-feet)

Industry	Treatment	% Total Treatment
Paper	26	37
Mineral Fuels	14	20
Petroleum and Coal	12	18
Food and Beverages	10	14
Chemical	5	7
Others	3	4
TOTAL	70	100

Since the Athabasca River basin contains the majority of firms in the Paper and Allied Industries group, that river basin experiences the greatest amount of waste water

treatment. Also, this group is not an urban-centred industry and as a result, the effluent must be treated by the industry itself. If, on the other hand, it were possible to pass this sewage to a municipal system, the industry would be relieved of much of its effluent treatment responsibilities. The Petroleum Industry in Calgary treated more waste water before discharge than did any other industry in any other city.

Consumptive Use:

The quantity of water consumptively used in the industrial process is essentially the difference between the intake volume and that of discharge. The consumptive use of water varies widely between industries and even between plants in the same industry, the latter difference being a reflection of contrasting technology.

The two-digit industry which consumptively uses more water than any other is that of Mineral Fuels. This is apparent from Tables 3 and 9. For convenience, Table 11 is derived showing the consumptive use of the major water-using two-digit industries in Alberta. These data for all two- and three- digit industries are presented in Tables VIII-35 to VIII-38.

TABLE 11

Consumptive Use of Water
By Major Two-Digit Industries
Alberta, 1972
('000 acre-feet)

Industry	Consumptive Use	% of Total Consumptive Use
Mineral Fuels	77	82
Chemicals	5	5
Paper	4	4
Petroleum	2	2
Primary Metals	2	2
Food and Beverages	2	1
Others	3	3
TOTAL	95	100

Since the Mineral Fuels Industry outweighs all others in terms of the consumptive use of water, it would be interesting to show which three-digit industry or industries of this group is responsible. Table 12 is a breakdown of the Mineral Fuels Industry into its three-digit components showing their respective consumptive water use patterns.

TABLE 12

Consumptive Use of Water
By the Three-Digit Mineral
Fuels Industries:
Alberta, 1972
('000 acre-feet)

Industry	Consumptive Use	% of Total Consumptive Use
Coal	1	1
Natural Gas	19	25
Oil	57	74
TOTAL	77	100

It is evident from Table 12 that the Oil Extraction Industry is the most significant contributor to the Mineral Fuels Industry having the position of largest consumptive user of water in Alberta at the present time. It could be argued that this use of water is a form of storage for future use. At any rate, estimates of future water requirements must involve discussion regarding potential technological changes and their impact on water use.

The river basin which has the largest absolute consumptive use of water by industry is the North Saskatchewan River basin. Most of the consumptive use of water by all industries except the Paper and Allied

Industries occurs in this basin. The Athabasca River basin follows next.

The Chemical Industry of Edmonton gives that city the distinction of having the highest industrial consumptive use of water in the province. The Petroleum Industry is also a significant contributor to this fact.

Summary of the Results

The Mineral Fuels Industry is by far the largest industrial user of water in Alberta at the present time in terms of both intake and consumptive use. More specifically, the Oil Extraction subset of this group is the largest three-digit water user, with nearly 57 thousand acre-feet of intake and essentially zero discharge. On a percentage basis, this latter industry withdraws approximately 20 per cent of the total withdrawals, and consumes nearly 60 per cent of the total consumption of water by industry.

Nearly 40 per cent of the water withdrawals for industrial purposes occurs in the South Saskatchewan River basin. Water use by the Petroleum and Chemical Industries contribute significantly to this situation. Most of the water used by industry is obtained from non-public sources, those being primarily private wells in this region. It is interesting to note that only 12 per cent of the water

intake by industry across the province is obtained from public sources. This is likely to have implications regarding the role which the price of water plays in determining the quantity of water demanded by industry as a whole.

Water recirculation was found to be the major source of gross water applied in most industries. The degree of recirculation was highest in the Primary Metals and Metal Fabricating industries. These industries have heat-generating processes which require cooling. For this reason vast amounts of water are used for cooling; since high water quality is not significant for this use, it can be used repeatedly.

It is reasonably safe to assume that, since the vast majority of water used in industry was obtained from private sources, industries themselves are responsible for what happens to the discharge and hence for the treatment of waste water. Just under half of the industrial waste water is treated privately prior to discharge. Treatment of waste water is industry-specific; that is, certain industries discharge waste water that is more deleterious than others.

The large quantities of water which are consumptively used by the Oil Extraction Industry must be viewed from two separate planes. On one hand, vast quantities of water are

accumulatively withdrawn by this industry from future use. This would have an impact on the production functions of other users of water if it were to decrease the availability of water to other uses and users. On the other hand, when this quantity of water is witheld from subsequent use, possible detrimental affects from its being unclean are absent. However, this latter arguement is less significant in light of recent governmental legislation aimed at cleaning up waste water at its source.

The assurance of sufficient supplies of water is important to industry. Equally important is the state in which industry leaves the water once it has been used. Any discussion, therefore, regarding industrial water use must necessarily be both quantitative and qualitative in nature. For this reason, Chapter III is an attempt to relate current supplies to current demands for water by industry in the province as well as to relate this supply to demands by industry over time. Quality aspects relating to industrial water use are discussed in Chapter IV.

Chapter III

Current and Projected Industrial Water Demand: Its Relation to Supplies of Water in Alberta.

Introduction

On the basis of the survey analysis reported in Chapter II, the demand for water by industry in Alberta during 1972 was calculated at approximately 270 thousand acre-feet. The geographic distribution of this demand was also examined on a river basin basis. The relation of industrial water demand together with the demand of all other uses to the existing supplies of water is of paramount importance. The purpose of the following section, therefore, is to relate the current demand for water in all uses to the existing supplies. The demand for water in this section does not include water for recreational and environmental uses. Further, no attempt is made to examine water demand from a seasonal or sub-basin approach. The demand for water is assumed to be homogeneous over time and across the respective river basins. Subsequent research should relax these simplifying assumptions in order to provide better estimates of water demand. The supplies of water are those measured by hydrometric stations at selected points along the river. In most cases, these flows are not

natural but are modified by control structures; the result is that potential shortages of water to some degree have already been anticipated. Also, no consideration is given to obligations for the province regarding delivery of water to downstream provinces. No consideration is given to return flows which are considerable in most industries, and in the agricultural sector in 'wet' years. Furthermore, because there is a considerable degree of interaction between surface and ground water, it is also assumed that surface flows are necessary to generate ground water availability. For example, most of the water obtained from ground water sources in the Calgary area is pumped from gravel beds adjacent to the river. These assumptions regarding the supply of water in Alberta should also be examined closely in subsequent research.

Not only is the current situation with regard to water demand and supply of importance, but future demand in relation to supply should also be examined. There are various methodologies in the literature which have been used to estimate future water demand by industry; a discussion of these approaches in light of their applicability in Alberta is undertaken. Subsequent to this discussion, projection of industrial water demand is made based on the most appropriate methodology. This future industrial demand for water is then related to supplies so that possible areas of

conflict and policy concern may be noted.

Current Industrial Water Demands in Relation to Existing Supplies

Nearly 80 per cent of the water withdrawn for industrial purposes in Alberta during 1972 was supplied by surface sources, primarily rivers. Due to ice formations, the winter is a critical time with respect to surface water availability. Therefore, if there are sufficient supplies to meet the demand for water during this period, the possibility of water shortages is minimized.

One method of depicting the flow characteristics of a river over time is by means of a frequency-discharge curve. This curve is the locus of points showing the percentage of the time during the year which a given volume of flow (measured in cubic feet per second) can be expected to be equalled or exceeded. The frequency-discharge curves generated for this study are based on about 50 years of data[1] and are presented, for the five river basins in Alberta, in Figures 3 through 7.

One way in which to relate the demand for water--here

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1. Water Survey of Canada. Historical Streamflow Summary, Alberta to 1970. (Ottawa: Department of the Environment, 1972).

FIGURE 3

FREQUENCY – DISCHARGE CURVE

PEACE RIVER

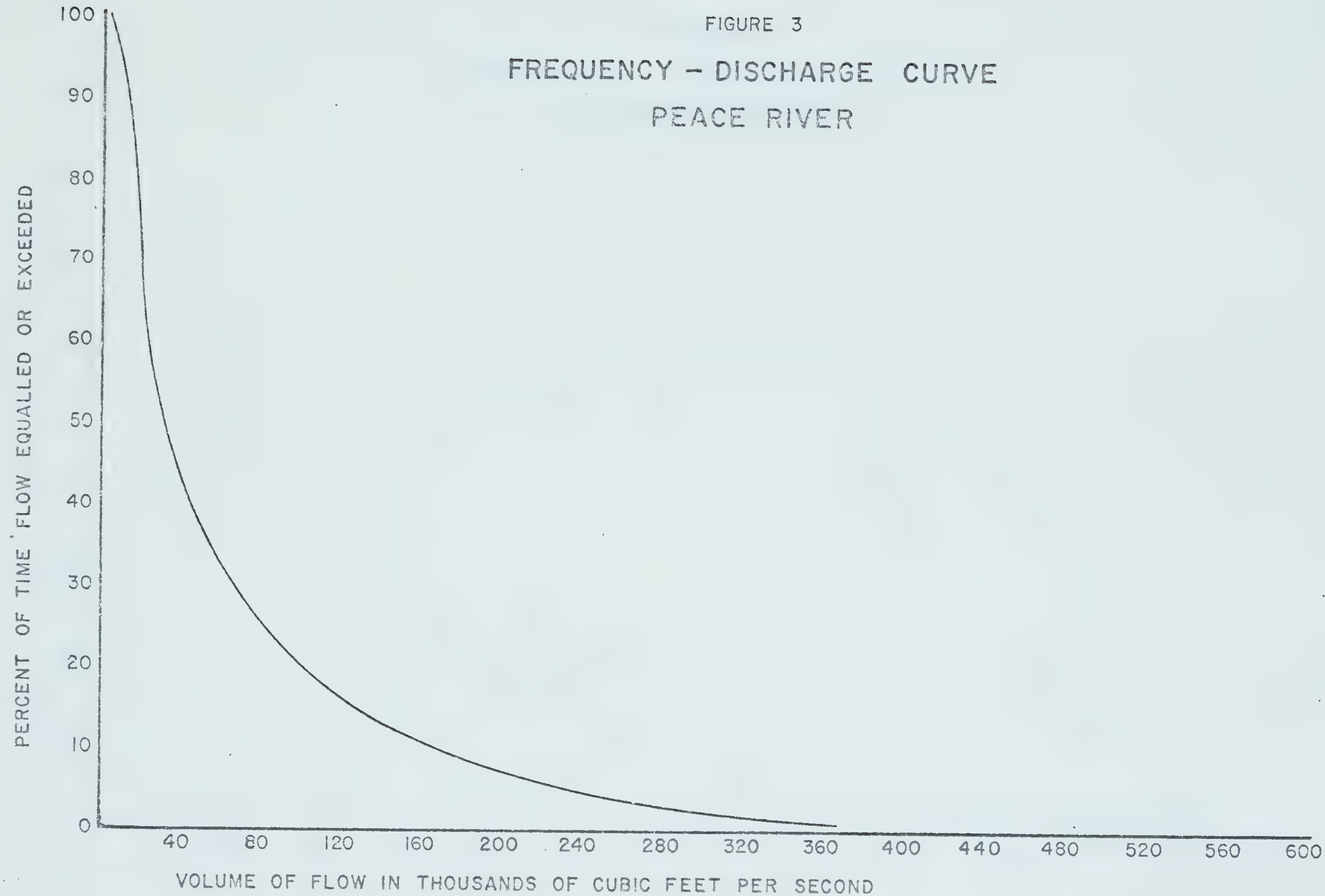


FIGURE 4

FREQUENCY - DISCHARGE CURVE
ATHABASCA RIVER

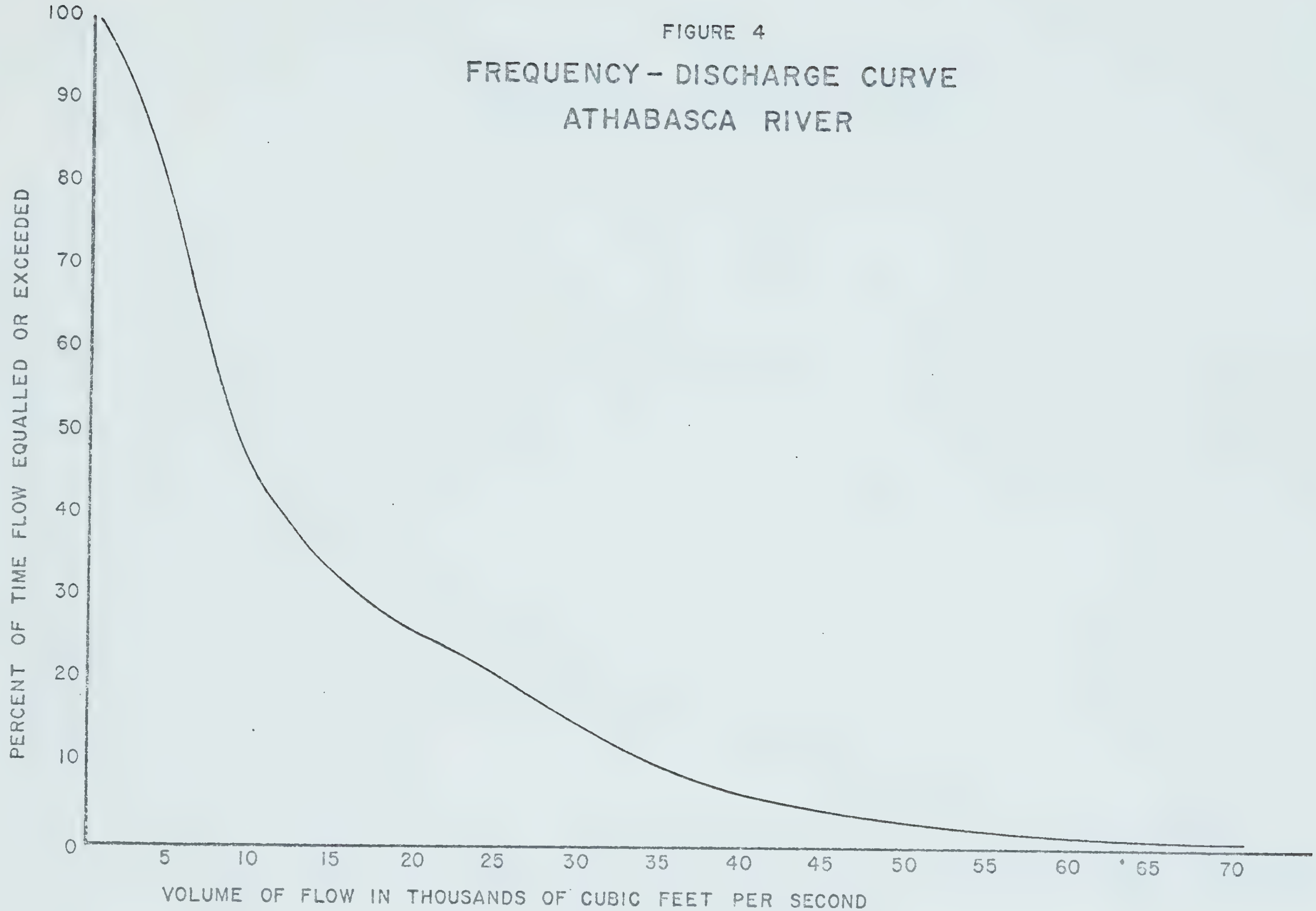


FIGURE 5

FREQUENCY DISCHARGE CURVE
NORTH SASKATCHEWAN RIVER

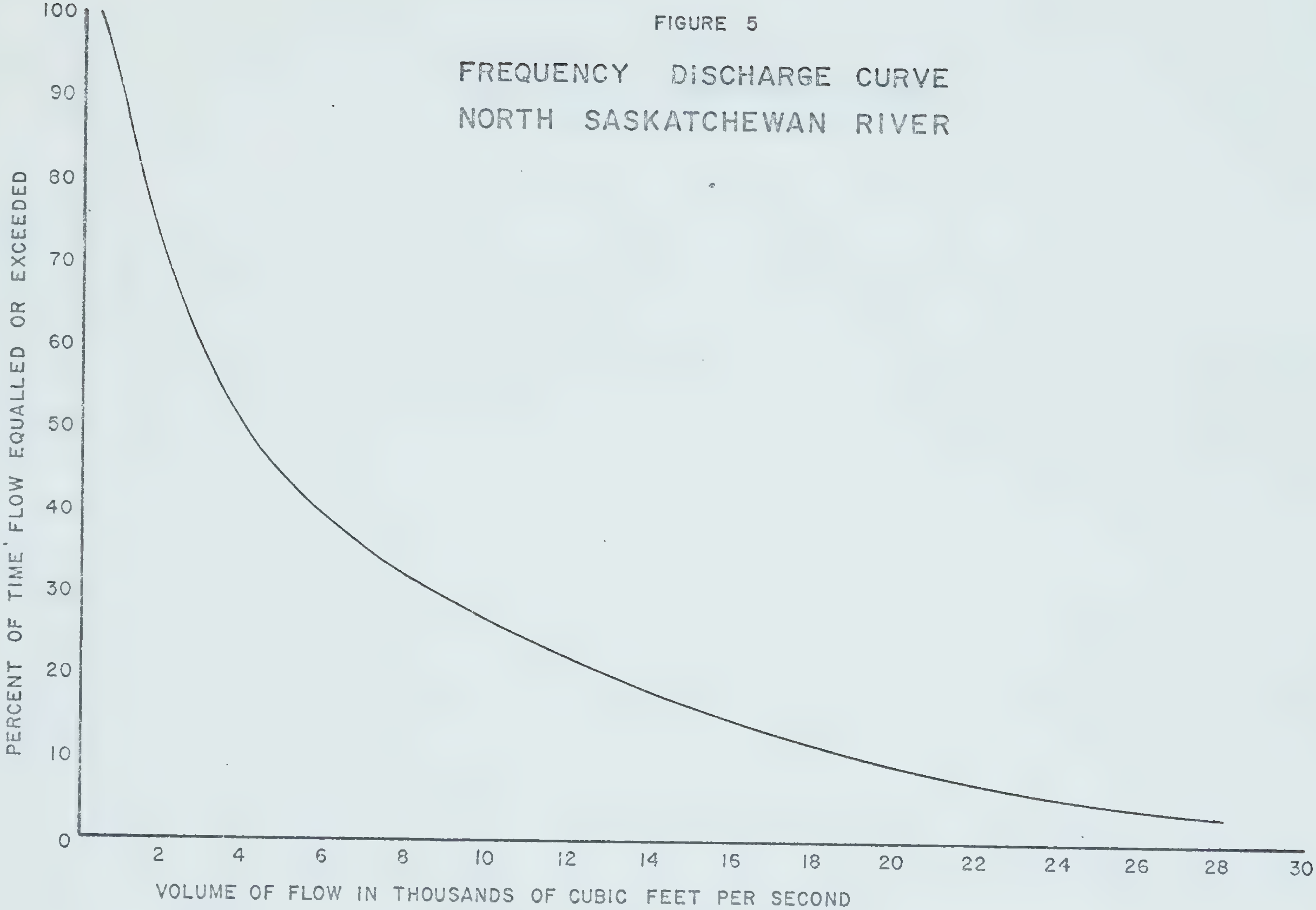


FIGURE 6

FREQUENCY DISCHARGE CURVE
RED DEER RIVER

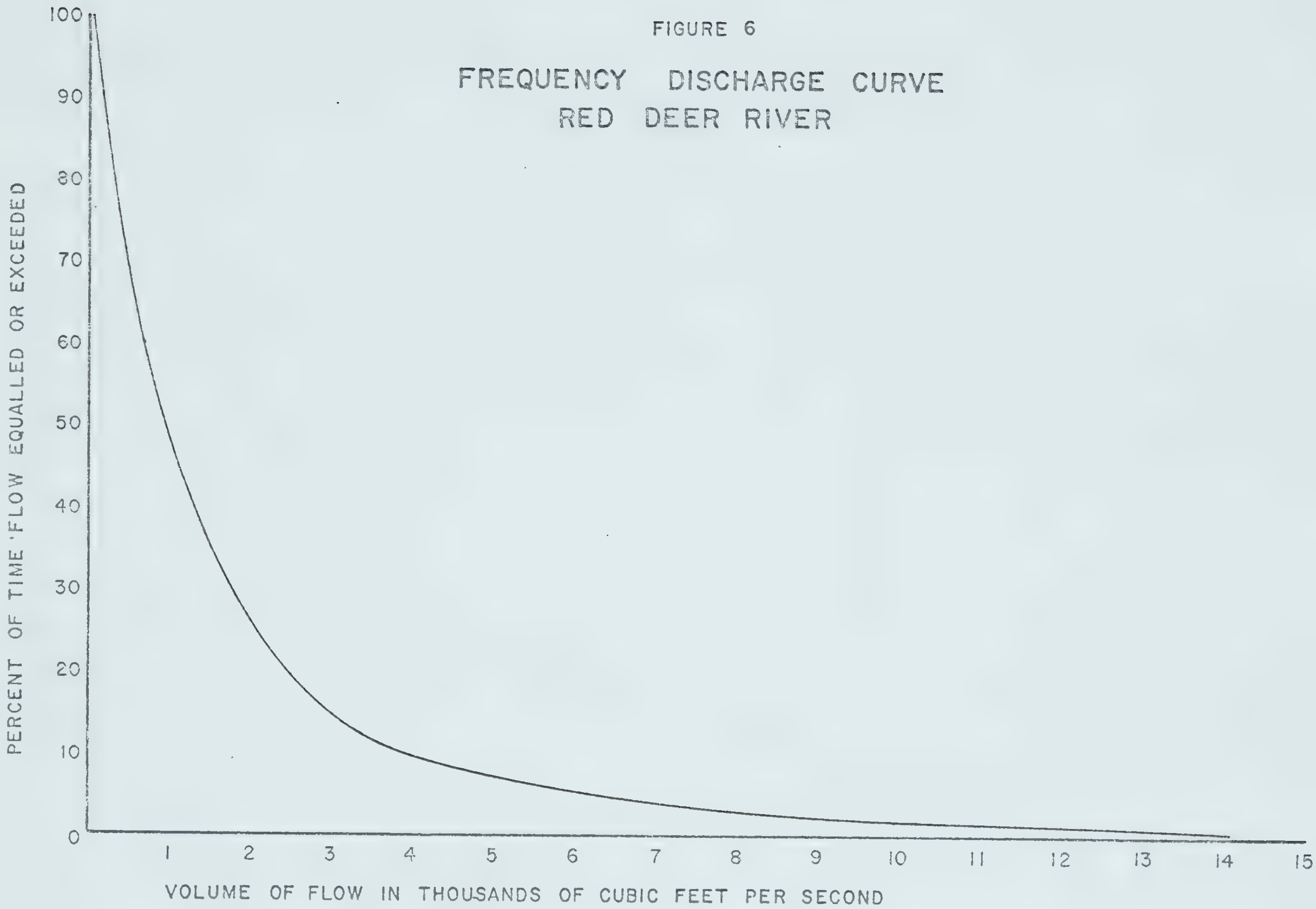
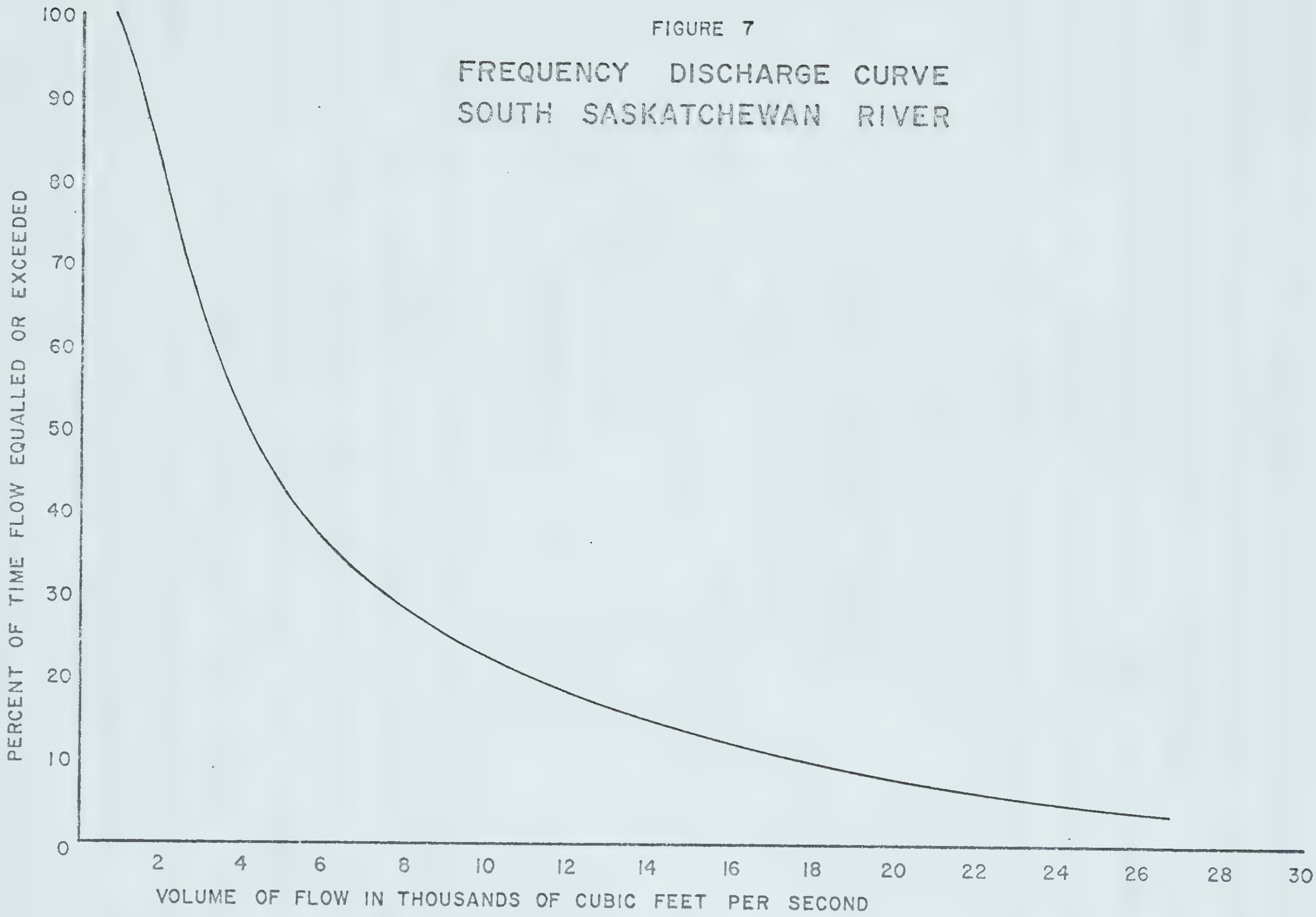


FIGURE 7

FREQUENCY DISCHARGE CURVE
SOUTH SASKATCHEWAN RIVER



assumed to be industrial water intake--to existing supplies is to determine the rate of flow of water required to meet that demand and then to compare this rate with that of the stream. The industrial intake volumes for the respective river basins are converted to rates of flow[2] and are presented in Table 13. The rates of flow required to meet

Table 13

Rate of Flow Required
To Meet Industrial Water
Demand: Five River Basins
Alberta, 1972.
(cubic feet per second)

River Basin	Rate of Flow
Peace	15
Athabasca	107
North Saskatchewan	93
Red Deer	11
South Saskatchewan	145

the demand for water by industry appear small in Table 13 relative to the flows shown in Figures 3 through 7. Since industrial water demand is small relative to total demand, meaningful demand-supply relationships must necessarily include the use of water by all users in Alberta. Total demand, on a river basin basis, is estimated by utilizing the following crude, but not unrealistic, assumptions: (1)

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2. The rate of flow is converted to an annual volume by the conversion formula: 1 cubic foot per second = 724 acre-feet per year.

all water used for irrigation purposes is specific to the South Saskatchewan River basin. The consumptive use by this sector ranges from about 0.2 to 1.3 million acre-feet per year (a value of 1.3 million acre-feet per year in used here)[3]; (2) in the South Saskatchewan River basin approximately 50,000 acre-feet of water are required annually for municipal purposes; and (3) total water demand in the Peace, Athabasca, North Saskatchewan, and Red Deer River basins could be estimated by adding 10%, 1%, 50%, and 20% respectively to the industrial water demand of each river basin. The rates of flow of water required to meet these total water demand estimates are presented in Table 14.

A comparison of Table 14 with Figures 3 through 7 reveals potential shortage problems in the South Saskatchewan River basin. Regarding the peak demand situation for water for irrigation purposes (at 1.3 million acre-feet per year), it would appear that about 85% of the time, flows are adequate to meet total water demand. The demand forirrigation water is presumably greatest when the supply is the smallest, that is, in 'dry' years. Close monitoring of water demand-supply relationships in the South

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3. Information Files. Water Resources Division. Alberta Department of the Environment.

Saskatchewan River basin is required. However, the

Table 14

Rate of Flow Required
To Meet the Water
Demand of All Uses:
Five River Basins
Alberta, 1972.
(cubic feet per second)

River Basin	Rate of Flow
Peace	17
Athabasca	108
North Saskatchewan	140
Red Deer	13
South Saskatchewan	2010

industrial sector in this basin should have an adequate water supply since, in most cases, firms in this sector are located upstream of irrigated farmland.

It would appear overall that there are at present adequate supplies of water to meet the demand of industry in the province. In most cases, the industrial demand for water is small relative to available supplies, although season fluctuations in both water demand and supply have not been analysed. The inclusion of the water demand for all uses would suggest potential water shortages in the South Saskatchewan River basin. That industrial water demand relative to the supply is insignificant today, does not necessarily imply the same will be true in subsequent years. Therefore, estimates of anticipated levels of industrial

water demand are required. There are various techniques which have been used to accomplish this task; they are outlined in the following section along with discussion regarding the practicality of their use in Alberta.

Alternative Methodologies For Estimating Industrial Water Demand

The approaches to industrial water demand forecasting that will be considered are: (1) the extrapolation of existing trends; (2) the use of input demand functions based upon neoclassical production theory; (3) the (average and marginal) fixed coefficients approach measuring direct effects only; (4) input-output analysis; and (5) linear programming. The latter three approaches, it will be seen, are conceptually related in that they are variants of methods based on the assumption of linear production technology.

Extrapolation of Existing Trends

The most simple technique for estimating the level of future demand for water by industry is mere extrapolation of existing trends. Although this technique is not particularly elaborate, it does lend itself to the task at hand in the sense that future requirements for water by the industrial

sector are assumed to follow similar trends to those in the past.

The extrapolation procedure can be made somewhat more sophisticated by utilizing a weighted moving average procedure. In this case, the observations are weighted in favor of the more recent (and probably more pertinent) ones. Assuming four data points existed, the fifth could be estimated as follows:[4]

$$WD^5 = WD^4 + (4WD^4 - 3WD^3 - WD^1)/6$$

where: WD^5 = the projected water demand in period 5
WD^4 = the observed water demand in period 4
WD^3 = the observed water demand in period 3
WD^1 = the observed water demand in period 1.

Another approach to forecasting the demand for water by industry could be the derivation of a demand function for water by industry based on neoclassical production theory.

The Water Demand Function: Neoclassical Production Theory

The demand for water, in an industrial context, is essentially a derived demand. That is, water is demanded by industry as an input to be used in the production of some final commodity. Using the conventional assumptions of neoclassical production theory (perfect competition, profit-

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4. For the derivation of this formula, see Appendix VI.

maximizing behaviour, smooth isoquants implying input substitutability, and sc cn), the derived demand for water can be determined as a function of its own price, the price of other inputs, and the price of the final commodity.[5] According to this model, a change in the price of water implies a change in the quantity of water demanded by industry while a change in either the price of the other inputs or the price of the final commodity is followed by a change in the demand for water. The responsiveness of the change in the quantity of water demanded to a change in its price is denoted as the price elasticity of demand. If there is little response to a change in the price of water, the demand function is termed inelastic while a relatively large change in the quantity of water demanded resulting from a change in its price reflects on elastic demand function.

There are certain problems inherent in the application of neoclassical production theory to industrial water demand. The major concern centers on the price of water variable in the industrial water demand function. It was established in Chapter II that nearly 90 per cent of the water withdrawn by industry in 1972 in this province is privately supplied; that is, water in most cases is not

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5. J. Henderson and R. Quandt, Microeconomic Theory: A Mathematical Approach (New York: Mc Graw Hill Book Company, 1971), p. 69.

purchased in a market as are other inputs in the productive process. As a result, the self-supply of water does not allow the market mechanism to function effectively in establishing price-quantity relationships since those who demand and supply water are frequently the same individuals.[6] As a proxy for water costs of those firms with self-supply, the marginal cost of acquisition might be used.[7]

Even if a firm is faced with purchasing water for its productive process from a municipal system, the costs of such expenditures are in general small relative to the total costs of production. For demonstration purposes only, firms located in Calgary and purchasing water from that municipal system were imputed costs for the purchase of water by applying the water rate schedule (see Appendix IX) to their volumes of intake for 1971.[8] These costs as a per cent of total production costs are shown in Table 15 for selected industries. This table shows that the cost of water for

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6. S. V. Ciriacy-Wantrup, Conceptual Problems in Projecting The Demand for Land and Water (Berkeley: University of California, 1959), p. 5.
7. W. Johnston, The Economists Role in Water Pricing (Davis: University of California), p. 34.
8. 1971 was chosen since this is the most recent year for which production cost data are available on an industry basis. See: Alberta Bureau of Statistics Preliminary Principal Statistics, Manufacturing Industries, Calgary, 1971 (Edmonton,1973).

industry relative to total production costs is indeed small.

Table 15

Water Costs Relative to
Total Production Costs:
Selected Industries,
Calgary, 1971.

Industry	Water Costs as a per cent of Total Production Costs
Food and Beverage	0.1
Primary Metals	0.1
Metal Fabricating	0.02
Non-Metallic Mineral	0.1
Chemical	0.4

It would appear, therefore, that since the costs of water is a minute consideration relative to the costs of all inputs, an increase in the price of water would produce little or no change in the quantity of water, implying an inelastic demand curve for water by industry. Theoretically, this is a relevant conclusion since " ... demand for an intermediate good or a factor of production will be more elastic the larger its share in the cost of the final product."[9]

That the cost of water is an exceedingly small portion of total production costs is supported by research conducted

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9. G. Reynolds, Economics: A General Introduction (Homewood: Richard D. Irevin, Inc., 1963), p. 105.

in the State of Washington.[10] It was found that in most industries the cost of water was one per cent or less of total production costs. It was also determined that "... it would take a 200 per cent change in the price of water for the most water-intensive aluminum firm in Washington to equal, in cost terms, a 10 per cent change in wage rates."[11] This would tend to suggest that, in the estimation of industrial water demand, even if the price of water variable existed (or a suitable proxy were used), the degree of substitutability between water and other inputs in response to relative input price changes is apt to be quite limited. A possible substitute for intake water might be recirculated water, over a certain range of water prices. If this were the case, the hypothesized inelastic demand function for water by industry would become more elastic depending on the degree of substitutability between recirculated and intake water. However, one is led to the consideration of methodologies in which input substitutability is not possible. The final three methodologies discussed--the fixed (average and marginal) coefficients approach, input-output analysis, and linear programming--in some measure are based on linear production technology in which input

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10. G. Brown, "Industrial Water Demand," <u>Forecasting the Demands for Water</u>, ed. W. R. D. Sewell et al (Ottawa: Department of Energy, Mines and Resources, 1968).
11. Ibid, p. 128.

substitutability is zero.

Linear Production Approaches

A linear production activity is characterized by a process in which one or more outputs are produced in fixed proportion by the use of one or more inputs in fixed proportion.[12] As a result, a proportionate change in the quantity of inputs used results in a proportionate change in the quantity of output produced. If, for example, one output is produced by two inputs, the productive process can be described by a set of coefficients a^i (i=1,2) which states the amount of input x^i required to produce one unit of output, q. That is:

$$a^i = x^i/q \qquad i=1,2$$

The required amount of input x^i needed to meet a given level of production, q, is then determined by:

$$x^i = a^i q \qquad i=1,2$$

Since the level of output is in some fixed proportion to the

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12. This section is based on: J. Henderson and R. Quandt, Microeconomic Theory, p. 335.

quantity of inputs used, the maximum level of output for the two inputs is determined by:

$$q^{max.} = \text{minimum } (x^1/a^1,\ x^2/a^2)$$

Therefore either factor x^1 or x^2 could be a limiting one with respect to the level of output.

The Average Coefficients Approach

A model for estimating future demands for water would be functional if based on a linear production function. Since there is assumed a fixed relationship between the level of output and the quantity of water required to produce that output, the quantity of output expected in a subsequent period would imply a derived demand for a certain quantity of water for that same period.[13] A model of this sort would not require the price of water variable; the quantity of water required per unit of output produced (average water coefficient) would, however, be necessary. In all cases, the value of production (termed gross sales) will be used as a proxy for the quantity of output.[14] Table 16

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13. G. Brown, Forescasting the Demands for Water, pp. 132-133.
14. Dominion Bureau of Statistics Manufacturing Industries of Canada: Prairie Privinces (Ottawa: Queen's Printer, 1963-1970).

presents the average water coefficients for selected industries in Alberta. These are derived by averaging the coefficients for the period 1968 to 1970 for the respective industries. It is apparent from this table that wide

Table 16

Average Water Coefficients, Selected Industries, Alberta (acre-feet of water per thousand dollars of gross sales)

Industry	Coefficient
Chemical	.57
Paper	.53
Petroleum	.20
Oil Extraction	.05
Non-Metallic Mineral	.04
Food and Beverages	.03
Primary Metals	.03

variations in the coefficients between industries exist. The Chemical Industry requires nearly 20 times as much water per thousand dollars of gross sales as the Food and Beverage, and Primary Metals industries. It is the average water coefficient approach which is utilized in this study to project future levels of industrial water demand.

The Marginal Coefficient Approach

Another way of examining the relationship between gross sales and water intake is an analysis of this relationship over time. Such a study shows the additional quantity of

water required to produce an additional quantity of output. This value is estimated by the marginal water coefficient which is a measure of the slope of the regression line where the dependent variable is the quantity of water intake (in acre-feet) and the independent variable is the value of gross sales (in 1961 dollars). Data for selected industries for the period 1968 to 1972 are used for the regression. Gross sales for 1971 and 1972 are estimated by the weighted moving average formula. The form of the equation is:

$$W = a + by$$

where W = the quantity of water demanded (acre-feet)
a = a constant
b = slope (marginal water) coefficient
y = value of gross sales in constant (1961) dollars.

The marginal coefficients are shown in Table 17. A

Table 17

Marginal Water Coefficients
Selected Industries: Alberta.
(acre-feet per thousand (1961)
dollars of gross sales)

Industry	Marginal Water Coefficient
Chemical	-0.97
Paper	0.75
Petroleum	-0.42
Oil Extraction	0.10
Non-Metallic Minerals	0.04
Food and Beverages	0.07
Primary Metals	0.06

comparison of the average water coefficients from Table 16 and the marginal ones of Table 17 shows that, in general,

the latter values are higher than the former. This would suggest that over time, water requirements per unit of output are increasing. However, the marginal coefficients for the Chemical and Petroleum industries are negative in sign; this is caused by a decline in gross sales accompanied by an increase in water intake over the study period. It would appear therefore, that for these two industries as well, water demand is also increasing marginally. One must conclude from this that, over time, there has been no impetus for industry to invest in water saving technology. Since, however, the data base for these time series regressions is extremely small, little confidence can be placed in the results. This technique as a procedure for estimating future levels of industrial demand is therefore rejected in this thesis. An enlarged data base, on a cross sectional basis for example, would greatly enhance the practicability of this approach.

The average and marginal fixed coefficients approaches relate potential changes in the demand for water by industry to anticipated changes in gross sales. This is the direct approach to estimating industrial water demand. However, as the output of an industry changes, so does the output of other industries having an input into that industry. These latter changes are termed indirect effects and should be accounted for in discussion regarding future demands for

water by industry. There is a technique which takes into consideration both the direct and indirect effects of changing output levels on industrial water demand; it is the input-output approach.

The Input-Output Approach

The interindustry or input-output approach to estimating future industrial water demands has been used in recent research.[15] However, fundamental to the use of this type of approach is a current input-output table; this is non-existent for Alberta at the present time. That input-output analysis is a useful tool for estimating the future demand for water by industry must be emphasized. For this reason, Appendix V presents a summary and discussion of the development of input-output analysis as well as a discussion of the way in which it can be used to estimate the future demand by industry for water.

The Linear Programming Approach

Linear programming is a further approach which has been used to estimate future water demand.[16] Since the price for

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15. E. Lofting, and P. McGauhey, Economic Evaluation of Water: Part IV (Berkeley: University of California, 1968).
16. Ibid., p. 65.

water in the industrial context is an elusive one, it would be tempting to utilize linear programming in order to derive shadow prices for the scarcity value of water used by the industrial sector. There are certain elements of this approach, though, which do not make it practicable for use in projecting potential industrial demand in Alberta. Building regional linear programming models in which water would be featured as a key constraint is beyond the scope of this thesis and, in general, is open to considerable methodological criticism.[17]

A number of possible approaches to the estimation of future industrial water demand in Alberta have been outlined. In summary, they are based on: (1) existing trends; (2) input demand functions; (3) fixed (average and marginal) coefficients; (4) input-output analysis; and (5) linear programming. Each alternative approach was examined with regard to its applicability to this province, and reasons given for accepting or rejecting each technique. The result of this examination is that it would appear that the approaches based on extrapolation and on fixed average coefficients would be most practicable. The next section utilizes these two approaches as comparisons in the

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17. S. V. Ciriacy-Wantrup. "Water Policy and Economic Optimizing: Some Conceptual Problems In Water Research" American Economic Review. 57 (May, 1967), p. 182.

estimation of future industrial water demand in Alberta.

Anticipated Future Water Demand By Industry in Alberta

The approaches used here to estimate the future demand for water by the industrial sector in Alberta is based on the average water demand coefficient and on trend extrapolation. In order to perform water demand estimations based on the average coefficient approach, one must have available estimates of future levels of production for the respective industries. Such estimates are not readily available at the present time; therefore, they are derived, for demonstration purposes, by using the weighted moving average technique applied to gross sale values of the Alberta industrial sector for the period 1967 to 1970 inclusively and are displayed to 1980 for the total industrial sector in Table 18. Table 19 shows the projected industrial water demand based on these levels of gross sales and on an average coefficient of 0.112.[18] For purposes of comparison, industrial water demand projected on the basis of the weighted moving average is also shown in Table 19. Estimated future levels of water demand for selected industries based the weighted moving average technique

18. This is the total industrial water demand in 1970 divided by the value of gross sales by the industrial sector in Alberta for that year.

applied to historical water intake values are shown in Tables VII-1 to VII-7. It is interesting to note from Table

Table 18

Projected Gross Sales
For the Industrial Sector,
Alberta 1973-1980
(millions of 1961 dollars)

Year	Projected Gross Sales
1973	2644
1974	2767
1975	2891
1976	3014
1977	3137
1978	3260
1979	3384
1980	3506

Table 19

Projected Industrial Water Demand
Alberta 1973-1980
('000 acre-feet)

Year	Water Demand (coefficient method)	Water Demand (moving average)
1973	295	278
1974	309	286
1975	323	294
1976	336	302
1977	351	310
1978	364	319
1979	378	327
1980	392	334

19 the slight divergence between the projected demands for water by industry based on two different procedures. In all

cases, those values based on the expected level of gross sales are more than those derived by the trend projection.

The conclusion to be drawn from the foregoing projections is that industrial water demands in total will increase over time. An exception is the Chemical Industry. Gross sales in this industry have been declining over the past four years; the result will be, of course, that water withdrawals will also decrease, based on the fixed coefficients approach. However, water intake in this industry has not been increasing during the recent past. The application of the moving average technique to the water withdrawal values for the Chemical Industry also indicates decreased water demand for this group.

Although there are no readily available estimates of future gross sales by the industrial sector, it must be concluded that the fixed coefficients approach to the estimation of industrial water demands is not to be discarded. It is difficult to project into the future with more than a small degree of accuracy due to unforseen changes in technology and product mix. The estimates presented in Table 19 may contain gross inacurracies; however, planning for the future in terms of water resource development must be based to some extent on past experience. That the projected values for industrial water demand do not

impinge on available supplies must be assured. A comparison of future demand for water by industry with supplies available is made in the following section.

Projected Industrial Water Demand Relative to Water Supplies

The foregoing projections, crude as they may be, indicate that the industrial demand for water is likely to increase over time. Water resource planners must be certain that sufficient supplies of water exist. To this end, Table 20 is presented showing, for the respective river basins, the rates of flow which must be available to meet the requirements of industry to 1980. It is assumed that the supply of water in each basin is relatively constant over time and the distribution of industrial water intake on a river basin basis will be not unlike that in 1972. A comparison of Table 20 with Figures 3 through 7 for the respective river basins does not suggest future water shortages with respect to industrial water demand. The inclusion of the water demand for all uses is presented in Table 21[19]. A possible trouble area is the South Saskatchewan River basin. Much more research is required regarding total water demand in this province before present

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19. Total water demand is estimated on the basis of the assumptions regarding Table 14.

and anticipated levels of this demand can be estimated with

Table 20

Rate of Flow of Water
Required To Meet Projected
Industrial Water Demand:
Five River Basins,
Alberta, 1973-1980
(cubic feet per second)

	River Basin				
Year	Peace	Athabasca	North Saskatchewan	Red Deer	South Saskatchewan
1973	15	111	96	9	150
1974	15	115	99	9	154
1975	15	118	102	9	158
1976	16	121	104	9	163
1977	16	124	107	10	167
1978	17	128	110	10	172
1979	17	131	113	10	176
1980	18	134	115	10	180

accuracy.

Table 21

Rate of Flow of Water
Required tc Meet Projected
Total Water Requirements:
Five River Basins,
Alberta, 1973-1980
(cubic feet per second)

	River Basin				
Year	Peace	Athabasca	North Saskatchewan	Red Deer	South Saskatchewan
1973	17	112	144	11	2029
1974	17	116	149	11	2033
1975	17	119	153	11	2037
1976	18	122	156	11	2042
1977	18	125	161	12	2046
1978	19	129	165	12	2051
1979	19	131	170	12	2054
1980	20	134	173	12	2058

Summary and Implications

In general, the quantity of water withdrawn by the industrial sector in Alberta is small relative to available supplies. Forcasts of these requirements based on both extrapolation of past trends and on fixed coefficients reveal that this demand, to the year 1980, will increase about 40 per cent. This estimated future demand, however, when compared with available supplies, also appears small.

It could be argued that forecasting industrial water demand into the future with any degree of confidence in the results is not practicable. For example, if technological changes in the Oil Extraction Industry were such that miscible gases were used exclusively for enhanced recovery, the result would be a decrease in the water demand of the industrial sector in this province by about 20 per cent. Also, industrial developments such as the Athabasca Tar Sands could require infinitely greater quantities of water due to changes in the extractive process at some point in the future. Developments in Coal Extraction Industry, in the way of coal gasification, could imply massive demands for water in that industry.[20] However, these advances are difficult to predict; projection must be made on the best available information. "If projections cannot be taken as predictions, are they of any value? The answer is definitely 'yes'. For the projections, based on the best judgments that can be made with available infomration, are far superior to the alternative - which is total ignorance."[21]

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20. "NAS: Water Scarcity May Limit Use of Western Coal," Science 181 (August 1973): p. 525. This article discusses the vast quantities of water required for coal gasification. The water shortage in the western U.S. could limit such a process. Since Alberta has vast coal reserves, and water, gasification would greatly increase the industrial demand for water.

21. Hittman and Associates, Inc. Forecasting Municipal Water Requirements, p. II-2.

If possible shortages were to occur, the key to the allocation of water among competing uses (when price appears to be ineffective) would be the system of water rights. The ability of this system to cope with possible conflicts due to water shortages is important. The water rights system in Alberta, although based historically on common law traditions of riparian water rights, would appear today to be closer to a system of appropriative water rights. That is, once a user has established use on a water body, that right of use cannot be forfeited unless abuse to that right (nonbeneficial use) can be demonstrated. Rights to water used for domestic purposes still remain riparian in nature, while all other users must apply for a license to use water. If application for this license occurs simultaneously with those of other users for the use of a body of water, the license is granted according to the following order of priority:[22] (1) domestic; (2) municipal; (3) industrial; (4) irrigation; (5) water power; and (6) other. Therefore, this appropriative system is applicable only to simultaneous application and, once the right is sanctioned, legislation does not allow for the reallocation of this right to another use (except where abuse is demonstrated). It would appear, therefore, that flexibility should be built into the system

22. The Water Resources Act, Chapter 388, p. 8.

of water rights in Alberta to the extent that reallocation to higher-valued uses is possible in times of water shortage. An alternative to the transfer of water rights would be planning for future water storage and diversion. This latter alternative might be more viable than the transfer of water rights from one use to another; however, the potential benefits and costs of such alternatives would have to be evaluated before a decision is made to use either as a tool to cope with problems of water shortage.

Implications to be drawn from a situation of adequate water supplies for industry do not address the question of water quality. Since most of the water withdrawn for industrial purposes in Alberta is supplied through private systems, the disposition of waste water in most cases is presumably the responsibility of the private firm. However, the consequences of poor or non-existent waste treatment practices are borne by subsequent users. This whole area of water quality relative to industrial activity is an important one. Chapter IV is a discussion of this relevant topic.

Chapter IV

Water Quality Implications of Industrial Activity in Alberta

Introduction

The quality implications of industrial waste-water discharge in Alberta cannot be ignored. It has been demonstrated in previous chapters that the quantity of water demanded by the industrial sector of the province does not in general encroach on existing supplies; therefore, it would appear that water quantity issues for the moment, are not pressing. To complete the examination of the industrial water scene in Alberta, discussion of quality aspects must be undertaken.

Since most of the water withdrawals by the industrial sector are private rather than municipally oriented in Alberta, one might hypothesize that the majority of the waste-water discharged by this sector is also privately undertaken. Evidence to support this hypothesis is, however, not forthcoming in this thesis. To the extent that the firm is individually responsible for the disposal of its waste water, that firm is also accountable for the quality of the effluent entering the receiving water body. This chapter is, therefore, a discussion of the water quality implications

resulting from industrial activity. As such, it examines the waste water discharge patterns of certain key industries as well as presents policy alternatives aimed at curbing potentially harmful rates of water quality deterioration linked to the industrial sector in Alberta. The economist's position regarding such policies is given special attention in the chapter.

Present Rates of Industrial Waste-Water Discharge in Alberta

A crude measure of the quantity of effluent in a body of water is provided by the Biochemical Oxygen Demand (BOD) test. BOD is a "test for estimation of waste water polluting effects in terms of the oxygen requirements for biochemical stabilization under specific conditions and time".[1] It is not clear, however, that the use of this test is a good indicator of the social costs imposed by various effluents. For example, small amounts of mercury in the water may be far more deleterious than large quantities of other wastes. However, the BOD criterion provides one measure of effluent loadings. Table 22 shows the pollution loadings in pounds per day into the five respective river basins resulting from all waste water discharges.

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1. P. Konopasek, Water Quality North Saskatchewan River: 1971-1972 (Edmonton: Alberta Department of the Environment, 1972), p. 13.

Table 22
Total Effluent Loading:
Five River Basins,
Alberta,
(pounds per day)

River Basin	BOD
Peace	1248
Athabasca	28351
North Saskatchewan	42728
Red Deer	4081
South Saskatchewan	89751

Source: An Inventory of Water Pollution Emissions in the Province of Alberta, 1970-1972 (Edmonton: Alberta Department of the Environment, 1972), p. 16.

It is apparent from Table 22 that the effluent loadings, on a daily basis, vary widely from river basin to river basin in Alberta. Again, these loadings are the result of waste discharges from all sources, that is, municipal, domestic, and industrial. Table 23 shows the daily effluent loadings attributable solely to industrial activity on a river basin basis.

Table 23 shows that in fact industrial contributions to total effluent loadings on a river basin basis are significant, primarily in the Athabasca and South Saskatchewan River basins. This is a similar conclusion to the one based simply on the volume of discharge (see Table VIII-29). The major contributor to the loading level and volume of discharge in the Athabasca River basin is the

Paper Industry, that is, the pulp and paper mill in this basin. The major sources, in terms of the volume of discharge volumes in the South Saskatchewan River basin, on

Table 23
Industrial Effluent Loadings,
Five River Basins:
Alberta.
(pounds per day)

River Basin	BOD	% Of Total Loadings in the Basin
Peace	nil	--
Athabasca	26950	95
North Saskatchewan	8127	19
Red Deer	212	5
South Saskatchewan	42833	48

Source: Same as Table 22.

the other hand, are the Chemical and Petroleum industries; however, the most of effluent loading based on pounds of BOD per day in this basin is the result of activity in the Food and Beverage Industry. This latter observation would imply that the level of waste water treatment in the Chemical and Petroleum industries is significantly greater than that in the Food and Beverage Industry in the South Saskatchewan River basin. It is beyond the scope of this thesis to make explicit claims regarding the effect on water quality in the respective river basins in this province as a result of industrial activity; however, to the extent that external diseconomies could be imposed on subsequent water users, an

examination of alternative public policies regarding water quality is justified. Such an examination follows a discussion of the rationale for government involvement in pollution abatement.

Rationale for Goverment Involvement in Pollution Abatement

It is an accepted fact that inherent in the production and consumption of goods is the accumulation of residuals.[2] These residuals must be disposed of, and the recipient of such disposition is generally the unpriced common property resources of air and water. The result is, then, that externalities occur. That is, some firm may discharge waste into a river, the result being that subsequent users of that water must bear the costs imposed by unclean water.

It has been argued that pollution control has public good characteristics.[3] To the extent that residuals are discharged into common property resources, collective or govermental action to curb such externalities is justfied, given the infeasibility of private bargaining solutions in most water and air pollution situations.[4] Policies of this

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2. A. V. Kneese, "Environmental Pollution: Economics and Policy" American Economic Review 61 (May, 1971): p. 155.
3. A. Breton, "Toward An Economic Theory of Pollution Control and Abatement," Pollution and Our Environment 3 (paper 29-1).
4. A. Kneese, "Environmental Pollution," pp. 153-154.

nature should be regional (river basins) rather than national in scope since most externalities of this nature are localzed. Governmental policies regarding water quality have tended to take various forms. A few of these along with those preferred by economists are presented in the following section.

Alternative Policies Regarding Water Quality

A number of various policies in the area of water quality have been enacted or proposed in recent years. Some of these are: (1) grants and subsidies; (2) accelerated depreciation allowances; (3) regulations and standards; and (4) effluent changes. Each policy will be discussed in turn with respect to its potential effectiveness in controlling water pollution in Alberta. The fourth alternative - effluent charges - is the one favored by economists.

Grants and Subsidies

This type of policy is generally applied to industrial or municipal sewage treatment systems. In Canada, the Central Mortgage and Housing Corporation has been empowered since 1960 to advance two-thirds of the costs of constructing municipal sewage treatment plants and, if the project is completed satisfactorily, 25 per cent of the loan

is foregiven. This type of policy, however, has serious economic drawbacks.[5] It is not equitable that an individual in one area of the country unaffected by pollution problems should pay to clean up those of some other location. Further, in times of inadequate federal funds, construction of sewage treatment facilities might be postponed. At the same time a subsidy system could tend to favor more expensive systems when possibly treatment systems internal to the respective firms might be less costly.

Depreciation Allowances

Since April, 1965, assets acquired by firms in Canada for the primary purpose of pollution control can be amortized at the rate of 50 per cent per year.[6] There are, however, a number of problems associated with such a scheme. Firstly, polluters are subsidized by non-pollutors if the loss in tax revenue is compensated by an increase in the taxation of the latter group. Secondly, these accelerated depreciation allowances are available for only capital assets; this could imply that less capital intensive

5. A. Kneese, "Environmental Pollution", p. 3.
6. This section is based on: L. Waverman, "Fiscal Instruments and Pollution: An Evaluation of Canadian Legislation," Economics: Contemporary Issues in Canada, ed. D. A. L. Auld (Toronto: Holt, Rinehart and Winston of Canada, Ltd, 1972).

techniques that might be less costly are not favored. A final problem associated with the depreciation allowance technique as a pollution control scheme is that the incentive for adaptation of this system at the firm level is partially a function of the firm's tax rate, that is, of the level of profits. This scheme is therefore of no value to firms operating at a loss (in the short run) and hence is practicable only for those firms which could afford abatement investment without the accelerated depreciation program.

Regulations

A regulatory policy regarding water quality is generally based on stream quality standards. For example, one criterion might be a specified level of dissolved oxygen existent at specific points in the water course. Therefore, each firm disposing waste into a particular water body must ensure that the quality of the effluent does not in fact detract significantly from the quality of the receiving water body. As a result, each firm's discharge must be monitored in order to establish the extent of treatment required to meet the standards set for that region. This procedure requires a substantial amount of consistent monitoring of the discharge; hence difficulties arise in enforcing the standards. A more appropriate system (the one

favored by economists) would be based on the principle that the pollutor should be made to bear the costs of pollution control. This scheme is essentially one of effluent charges. It should be mentioned that an effluent charge system would in fact incorporate segments of regulatory policy in the sense that some degree of monitoring would be necessary to ensure that each firm's effluent is of the quality established by the water management authority.

Effluent Charges.

A water quality management program founded on a system of effluent charges is based on two general concepts.[7] The first one is that the waste discharger should bear the costs of his activities which impose on the common property assets of society (air and water) and secondly, that a well integrated water quality management program would be most operational on a regional basis since pollution problems are regional in nature. The effluent charge is based on the amount and characteristics of effluent discharged into the common property resource and is a payment for the use of such disposal mediums.

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7. This section is based on: A. Kneese, "Environmental Pollution: Economics and Policy" American Economic Review 61 (May 1971): pp. 162-166.

The way in which a system of effluent charges would have an effect on water quality is as follows. The entrepreneur, when faced with charges to be paid for waste discharge, could determine the method which would be most suitable in his own situation to decrease pollution levels, or he could simply neglect abatement techniques and pay the effluent charge. The costs of the resultant abatement techniques might then be passed on the consumer who could pay the increased price for the commodity or alter his consumption habits. As a result there could be a shift to goods with a smaller environmental cost. This system of effluent charges offers some incentive toward abatement even at a low level of waste discharge while a system based on standards provides no incentive to decrease waste discharge beyond the required level, even though it might be accomplished inexpensively. Revenues generated by a system of effluent charges could be used for environmental quality improvements.

The federal government has a definite role to play in the establishment of regional water quality programs based on effluent charges. For example, the central goverment could, in conjunction with regional bodies, establish minimum effluent charges on all waste discharges above some minimum amount. The regional authorities could then consider this as a base line and would be encouraged to tailor the

charge structure to suit their own (local) water quality requirements. Such a policy would ensure that, on a national basis, there were no 'pollution havens' and that some consistent minimum water quality level existed nationally. The recent enactment of the Canada Water Act does make provision for such levels. Mention is made of effluent charges although the way in which they are to be set is not yet made explicit. This act is, however, a step in the direction of a water quality management scheme based on effluent charges.

A number of alternative water quality policies have been examined with respect to their potential effectiveness in curbing water quality deterioration. The alternatives are: (1) grants and subsidies; (2) accelerated depreciation allowances; (3) regulations and standards; and (4) effluent charges. Examination of each, in turn, determined that the most efficient system would be an effluent charge scheme based on realistic standards. Such a program would cause the firm to internalize to a large extent the social costs imposed by its productive activities in the sense that the firm pays for the use of the common property resource (air and water) as a receiving body for its waste discharge. Regional water quality programs should be established since pollution problems are themselves local in nature.

Conclusions

It has not been the purpose of this chapter to present judgments regarding water quality as a result of industrial activity in Alberta, but rather to point out those industries whose discharge could have the most deleterious effects. Possibly the greatest contribution of this chapter is the examination of alternative policies which could be implemented with a view to controlling the quality of industrial effluent entering the lakes and streams of this province.

The industrial group in Alberta which collectively discharges the greatest volume of waste water is the Chemical Industry. It was discovered, however, that the effluent of this group is not the most potentially deleterious based on BOD, although other tests on effluents may lead to different results. The Food and Beverage Industry (in the South Saskatchewan River basin) produces more BOD per day than any other industry. This factor, along with the consideration of the potential low flow problems in the South Saskatchewan River basin, suggests that close examination be made of this area. That the greatest volume of waste-water discharge does not necessarily imply the greatest hazard to water quality, would suggest that water quality programs should not be based solely on physical

discharge volumes. To the extent that there are other considerations regarding water quality policy formulations, an examination of alternative policy proposals was made.

The most appropriate water quality scheme discussed was that of effluent charges. This system would enforce the principle that 'the pollutor must pay' while at the same time attempt to enable entrepreneurs to decide on the least cost abatement program for their respective firms. The revenues derived by this system could be used for environmental quality improvements.

The impetus for an effluent charge scheme for water quality management could originate with the federal government. This could be accomplished by the senior government, together with the provinces and the regional water authorities, establishing minimum water quality standards which would create a base level for areas of the nation with similar water quality situations, with a charge for effluent loadings exceeding this level. This would avoid the possibility of 'pollution havens'. Under such a system, some flexibility in minimum standards might be possible across areas of the country with dissimilar water quality problems; furthermore, the river basin authorities could increase effluent charges from the minimum base level to generate the desired water quality in the basin.

There are certain implications to be drawn from the foregoing discussion in terms of Alberta water quality as it is affected by industrial activity. At the present time, the water quality program in this province is essentially regulatory in nature.[8] Prior to the construction of an industrial plant, application must be made with the Alberta Department of the Environment giving information, among other things, regarding the extent and quality of the proposed discharge of effluents. If these proposals are within the established guidelines, and all other aspects of the application are acceptable, approval in granted.

The water quality programme of the Alberta government could be made more efficient by the inclusion of an effluent charge scheme. Since the standards are already established and the monitoring of waste discharge is in effect, all the benefits (as outlined above) of an effluent charge system could be realized by the citizens of this province. Further examination of such a proposal is warranted in terms of enhancing the existing water quality program in Alberta.

8. Alberta Department of the Environment, Clean Water (Industrial Plants) Regulations, OC217/73.

CHAPTER V

Summary and Policy Implications

Summary

The purpose of this thesis has been to examine industrial water use in Alberta from both a quantitative and qualitative point of view. It has been an exercise in reviewing the pertinent policy issues regarding industrial water use in the province and proposing changes in water management policy which would enhance the administration of this resource.

The survey upon which this thesis is based reveals that 422 firms in the industrial sector of Alberta each withdrew more than one million gallons of water in 1972 amounting in total to about 270 thousand acre-feet. These firms are located in almost all parts of the province. However, the distribution of intake is not similar to that of industrial location; intake varied from a total of 8 thousand acre-feet in the Red Deer River basin to about 105 thousand acre-feet in the South Saskatchewan River basin. This would imply that some industries demand more water than others.

Firms involved in mineral fuel extraction collectively withdrew more water than those of any other industry in

Alberta in 1972. Most of the water demand of this group is located in the Athabasca River basin. The Mineral Fuels Industry deserves special attention. Of all the water which is consumptively used by the industrial sector in Alberta, the Mineral Fuels Industry uses over 80 per cent. This is primarily due to the large quantities of water which are withdrawn by the Oil Extraction subset of this group and are essentially not returned to the water system. It is interesting to note that nearly 90 per cent of the water withdrawn for industrial purposes is privately provided, primarily from surface sources.

Water discharged by the industrial sector in Alberta during 1972 amounted to about 176 thousand acre-feet. The largest single discharger of waste water is the Chemical Industry with about 66 thousand acre-feet. The salient factor regarding waste water discharge is not so much the volume discharged but the amount of treatment received prior to discharge.

Across all industries, about 40 per cent of all waste water is treated prior to discharge; some of the remaining 60 per cent is treated municipally. The quantity of waste water treatment ranged from essentially zero in some industries to nearly 97 per cent in the Paper Industry. The resultant quality of effluent is examined in a further

section.

The amount of water which is applied to the productive process that is derived from recirculated sources is an important factor in the analysis of industrial water demand. This portion, termed the degree of recirculation, was found to be the greatest in those industries requiring water primarily for cooling purposes. These same industries tended to be ones which did not use consumptively the largest volumes of water. Upon relating the volumes of water demanded by the industrial sector to existing supplies, it was determined that little or no conflict is apparent. The inclusion of all water uses revealed potential shortages in the South Saskatchewan River basin. For example, the rate of flow of water required to meet total water requirements in this basin is about 2010 cubic feet per second in Table 14, while the long term data reveal that, 85 per cent of the time, a flow of this magnitude is expected to be equalled or exceeded (see Figure 7). This conclusion is, of course, based on crude assumptions such as the quantity of water used for irrigation is about 1.3 million acre-feet annually (a peak situation), and the municipal water requirements are approximately 60,000 acre-feet per year. Each river basin in turn should be examined more closely with respect to total water demand.

An attempt was made in this thesis to estimate a demand function for water by industry so that future levels of water demand might be estimated. It was assumed that price has little effect on the quantity of water demanded since most of the water is privately provided, or is a very small portion of the total costs of production if purchased from some municipal system. It was hypothesized that the demand function for water by industry could in some cases become more price elastic if in fact recirculation of water were to become to some degree a substitute for intake water. This hypothesis was not pursued further. It was found, though, that the demand of water would be best estimated at the present time by assuming that its use was in some fashion fixed to the quantity of output produced and in general unrelated to price. Hence, projection of future levels of industrial water demand are linked (via the average water coefficient) to anticipated future levels of production. Potential water shortages in the South Saskatchewan River basin were apparent when the demand for water the industrial sector along with that of all other users was projected to the year 1980 and compared with the existing supply. The examination of industrial water demand in Alberta was completed with a discussion regarding this demand relative to water quality based on BOD.

The Food and Beverage Industry discharges more pounds

of BOD per day than does any other industry in Alberta. This is an interesting point to note since that industry ranks fifth in terms of the volume of waste water discharge and fourth based on the quantity of waste water treated prior to discharge. It would appear, based on the BOD criterion, that the extent of treatment in the Food and Beverage Industry is low relative to other industries in the province. This would imply that changes to existing policies regarding water quality in Alberta should be considered. To the extent that such changes should be anticipated, alternative water quality policies regarding abatement were examined.

A number of alternative water quality policies were discussed: (1) grants and subsidies; (2) accelerated depreciation allowances; (3) regulations; and (4) effluent charges. Each was examined in turn with respect to its ability to control the industrial discharge of effluents into the respective bodies of water in Alberta. A scheme based on effluent charges was proposed to be the most efficient policy since it would cause the entrepreneur to internalize some of the costs now imposed on users of the common property resources of society. An effluent charge would enable the firm to utilize that form of abatement which would achieve the required level of effluent quality at minimum costs or to decide to neglect abatement and pay all the effluent charges, or a combination of both. The

costs of such a program would be reflected in higher charges for the commodities produced by these firms, assuming such additional costs could be passed on to consumers; this could possibly result in a shift toward goods which are less costly in environmental terms. Revenues generated by an effluent charge scheme could be used for environmental quality improvement. The federal government would have a definite role to play in formulating such a scheme in terms of minimum rational effluent standards and charges.

Policy Implications

A number of implications for water management policy are implied by the results of this thesis. In general terms, these involve: (1) water pricing; (2) water law; (3) demand projections; and (4) water quality. Each implication is discussed in turn.

Water Pricing

Results of this study would imply that, in general, the price of water has little effect on the demand decisions of entrepreneurs in the industrial sector in Alberta. This is based on the observation that only a small portion of the water intake by industry in Alberta has a price in the sense that it is purchased as an input into the productive

process. Even for those firms which purchase water, such expenditures account for less than one per cent of the total cost of production. The implication for a policy is, therefore, that increases in the price paid for water by the industrial sector will likely have a minimal effect on the quantity demanded unless it can be demonstrated that there is a significant degree of substitution between intake and recirculated water. Since such a demonstration is beyond the scope of this thesis, it is assumed that price has little effect on the quantity of water demanded. This assumption is in line with economic theory. The implication of such an assumption is, therefore, that the price of water in the industrial sector is likely to be poor allocator of scarce water among competing uses, but would be a good tool for raising revenue for the construction of water management projects. Furthermore, this thesis supports the view that water should be priced at its true scarcity value and that the charge for water should be related to consumptive use. However, if the goal of water management policies is to alter the distribution of water among uses, price changes alone are likely to be an ineffective instrument. Institutional measures would appear to be more useful.

Water Law

The importance of institutional flexibility as a major thrust to redirecting water supplies to higher valued use can not be over-emphasized. The key institution in the water resources sphere is the system of water rights. Water rights in Alberta appear to be based on prior claim. However, present legislation does not allow for the reallocation of these rights to higher valued uses in times of water shortages. Flexibility of this nature should be explicit in Alberta water law. It is felt that effective planning regarding water storage and diversion schemes might be another measure for dealing with water shortages. The social benefits and costs of each measure would have to be made carefully before a decision is reach regarding the implementation of either as a method of coping with water shortage problems in Alberta.

Water Demand Projections

The estimation of future levels of industrial water demand is indeed a complex task. Such forecasts are in general based on existing technology and functional relationships; changes in either or both of these could

significantly alter subsequent levels of industrial water demand. For example, if the technology involved in enhanced recovery of oil were to change, the quantity of water demanded by the industrial sector could be greatly altered. Technological advances in the productive processes of industrial firms could either be water-saving or water-using in nature, causing induced changes in water demand. Industrial activity in subsequent years which is not anticipated at the present time would certainly effect the level of water demand by the industrial sector as a whole. In light of current trends, however, water shortages with respect to industrial water demand are not anticipated although possible areas of concern arise upon the inclusion of all water users in Alberta.

The existence of an adequate (or ample) water supply relative to demand does not necessarily imply the probability of economic growth due to potential industrial activity. Water availability is not a sufficient condition for industrial location. "Water is clearly a necessary input for all types of economic activity, but it can be transported, imported, conserved, recycled, refined, and reused at sufficiently low costs that its abundance in the natural environment is not necessary for most types of

economic activity".[1] Hence, the province cannot justifiably expect to induce an influx of industries due to ample water supplies.

The relationship between water resource development and economic growth is not necessarily a direct one. That is, if Alberta were to develop her water resources further for the sole purpose of enhancing economic growth, caution is urged.[2] There are a number of reasons for this. Firstly, the regional objective cannot focus only on the region in which the project is located at the neglect of all other regions since development in one region could be at the expense of other regions. Secondly, in cases where regional development plans are designed and evaluated by water resource development agencies, other more effective means of stimulating regional development may be neglected. Thirdly, most heavy water demanding industries are highly capital intensive; therefore, the direct effects of potentially accelerated growth in terms of employment opportunities and population are likely small.

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1. C. Howe, Water Resources and Regional Economic Growth in the United States, 1950 - 1960 (Washington: Resources for the Future, 1968), p. 8.
2. This section is based on: A. Freeman and R. Haveman, "Benefit-Cost Analysis and Multiple Objectives: Current Issues in Water Resource Planning," Water Research 6 (1970) pp. 923-930.

The overall implication concerning the quantitative aspects of industrial water demand in Alberta is that there would appear to be little need for concern at the present time. However, the seasonality aspects of both demand and supply of water have been ignored. It is recognized that short term water shortages could occur due to this fluctuation problem at the micro level. Overall, though, there would appear to be an adequate supply of water to meet the demand of the industrial sector in the province. There is, however, need for the examination of policies regarding water quality management.

Water Quality

Existing water quality policies in Alberta tend to be regulatory in nature. Proposed waste disposal systems of firms must meet certain standards before permission is granted for constraction. Fines and stopages could be imposed upon failure to meet given effluent quality standards.

A water quality scheme based on effluent charges could be adopted for Alberta. Such a program could use the existing standard as a base line, and could apply charges for exceeding these levels. The monitoring system required in an effluent charge scheme is already in existence. The

establishment of a water quality management program would be an equitable one since the pollutor is forced to internalize to some degree the costs he imposes on the rest of society.

Future Research Needs

This thesis is not intended to be an exhaustive analysis of water demand by the industrial sector in Alberta. Its purpose has been to examine the key issues involved. This study does, however, expose certain areas which merit further study.

There is need for future research into the spatial and temporal distribution of both the supply of and demand for water by the industrial sector in Alberta. Seasonal fluctuations in demand should be compared with those of supply. The distribution of both spatial and temporal considerations of water supply and demand on both a basin and sub-basin basis should also be examined. Such analyses would enable the water resource planner to plan more effectively for the future. This is especially important with reference to water use in the South Saskatchewan River basin were a more close examination is required of uses other than industrial since the agricultural sector in that basin uses the overwhelming bulk of the water.

Research should be extended into the area of marginal

water coefficients. The purpose of such an examination would be to establish if, over time, the technology surrounding industrial water demand in Alberta has been of a water-saving or water-using nature. Data regarding the level of production at the firm level would greatly enhance such an examination.

Independent estimates of the anticipated levels of production in the industrial sector should be undertaken. In this thesis they are estimated by using a weighted moving average technique. More sophisticated estimates of future gross sales, perhaps based on econometric models or on input-output analysis, would be useful in deriving industrial water demand estimations.

A clear examination should be made of the price elasticity of demand for water by industry. This study assumed the demand curve to be price inelastic; further research should be conducted regarding this assumption. The cost of water is shown in general to be small relative to total production costs which would imply a relatively inelastic demand curve for water. However, the substition of water for other inputs (such as recirculated water) would tend to make this curve more elastic.

A final area of industrial water demand which merits further study is that of the water quality implications. The

Biochemical Oxygen Demand criterion was used here as a measure of water quality; the real social costs of industrial waste water discharge may be more accurately measured by other tests. Additional research is also required with respect to the adaptation of a water quality management program based on effluent charges for Alberta.

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Appendix I

Standard Industrial Classification

Code

LIST OF GROUPS AND CLASSES

Division 1-Agriculture

Major Group 1-Experimental and Institutional Farms

001 Experimental and University Farms
003 Institutional Farms

Major Group 2-Farms (except Experimental and Institutional Farms)

011 Livestock and Livestock Combination Farms
013 Field Crop and Field Crop Combination Farms
015 Fruit and Vegetable Farms
017 Other Crop and Livestock Combination Farms
019 Miscellaneous Specialty Farms

Major Group 3-Services Incidental to Agriculture

021 Services Incidental to Agriculture

Division 2-Forestry

Major Group 1-Logging

031 Logging

Major Group 2-Forestry Services

039 Forestry Services

Division 3-Fishing and Trapping

Major Group 1-Fishing

041 Fishing

Major Group 2-Fishery Services

045 Fishery Services

Major Group 3-Hunting and Trapping

047 Hunting and Trapping

Division 4-Mines(including Milling), Quarries and Oil Wells

Major Group 1-Metal Mines

051 Placer Gold Mines
052 Gold Quartz Mines
057 Uranium Mines
058 Iron Mines
059 Miscellaneous Metal Mines

Major Group 2-Mineral Fuels

061 Coal Mines
064 Crude Petroleum and Natural Gas Industry

Major Group 3-Non-Metal Mines(except Coal Mines)

071 Asbestos Mines
072 Peat Extraction
073 Gypsum Mines
079 Miscellaneous Non-Metal Mines

Major Group 4-Quarries and Sand Pits

083 Stone Quarries
087 Sand Pits or Quarries

Major Group 5-Services Incidental to Mining

096 Contract Drilling for Petroleum
098 Other Contract Drilling
099 Miscellaneous Services Incidental to Mining

Division 5-Manufacturing Industries

Major Group 1-Food and Beverage Industries

101 Meat and Poultry Products Industries
102 Fish Products Industry
103 Fruit and Vegetable Processing Industries
104 Dairy Products Industry
105 Flour and Breakfast Cereal Products Industry
106 Feed Industry
107 Bakery Products Industries
108 Miscellaneous Food Industries
109 Beverage Industries

Major Group 2-Tobacco Products Industries

151 Leaf Tobacco Processors
153 Tobacco Products Manufacturers

Major Group 3-Rubber and Plastics Products Industries

162 Rubber Products Industries
165 Plastics Fabricating Industry,n.e.s.

Major Group 4-Leather Industries

172 Leather Tanneries
174 Shoe Factories
175 Leather Glove Factories
179 Luggage, Handbag and Small Leather Goods Manufacturers

Major Group 5-Textile Industries

181 Cotton Yarn and Cloth Mills
182 Wool Yarn and Cloth Mills
183 Man-made Fibre, Yarn and Cloth Mills
184 Cordage and Twine Industry
185 Felt and Fibre Processing Mills
186 Carpet, Mat and Rug Industry
187 Canvas Products, and Cotton and Jute Bags Industries
188 Automobile Fabric Accessories Industry
189 Miscellaneous Textile Industries

Major Group 6-Knitting Mills

231 Hosiery Mills
239 Knitting Mills (except HosierMills)

Major Group 7-Clothing Industries

243 Men's Clothing Industries
244 Women's Clothing Industries
245 Children's Clothing Industry
246 Fur Goods Industry
248 Foundation Garment Industry
249 Miscellaneous Clothing Industries

Major Group 8-Wood Industries

251 Sawmills, Planning Mills and Shingle Mills
252 Veneer and Plywood Mills
254 Sash, Door and Other Millwork Plants
256 Wooden Box Factories
258 Coffin and Casket Industry
259 Miscellaneous Wood Industries

Major Group 9-Furniture and Fixture Industries

261 Household Furniture Manufacturers
264 Office Furniture Manufacturers
266 Miscellaneous Furniture and Fixtures Manufacturers
268 Electric Lamp and Shade Manufacturers

Major Group 10-Paper and Allied Industries

271 Pulp and Paper Mills
272 Asphalt Roofing Manufacturers
273 Paper Box and Bag Manufacturers
274 Miscellaneous Paper Converters

Major Group 11-Printing, Publishing and Allied Industries

286 Commercial Printing
287 Platemaking, Typesetting and Trade Bindery Industry
288 Publishing Only
289 Publishing and Printing

Major Group 12-Primary Metal Industries

291 Iron and Steel Mills
292 Steel Pipe and Tube Mills
294 Iron Foundries
295 Smelting and Refining
296 Aluminum Rolling, Casting and Extruding
297 Copper and Copper Alloy Rolling, Casting and Extruding
298 Metal Rolling, Casting and Extruding, n.e.s.

Major Group 13-Metal Fabricating Industries (except Machinery and Transportation Equipment Industries)

301 Boiler and Plate Works
302 Fabricated Structural Metal Industry
303 Ornamental and Architectural Metal Industry
304 Metal Stamping, Pressing and Coating Industry
305 Wire and Wire Products Manufacturers
306 Hardware, Tool and Cutlery Manufacturers
307 Heating Equipment Manufacturers
308 Machine Shops
309 Miscellaneous Metal Fabricating Industries

Major Group 14-Machinery Industries (except Electrical Machinery)

311 Agricultural Implement Industry
315 Miscellaneous Machinery and Equipment Manufacturers
316 Commercial Refrigeration and Air Conditioning Equipment Manufacturers
318 Office and Store Machinery Manufacturers

Major Group 15-Transportation Equipment Industries

321 Aircraft and Aircraft Parts Manufacturers
323 Motor Vehicle Manufacturers
324 Truck Body and Trailer Manufacturers
325 Motor Vehicle Parts and Accessories Manufacturers
326 Railroad Rolling Stock Industry
327 Shipbuilding and Repair
328 Boatbuilding and Repair
329 Miscellaneous Vehicle Manufacturers

Major Group 16-Electrical Products Industries

331 Manufacturers of Small Electrical Appliances
332 Manufacturers of Major Appliances (Electric and Non-Electric)
333 Manufacturers of Lighting Fixtures
334 Manufacturers of Household Radio and Television Receivers
335 Communications Equipment Manufacturers
336 Manufacturers of Electrical Industrial Equipment
338 Manufacturers of Electric Wire and Cable
339 Manufacturers of Miscellaneous Electrical Products

Major Group 17-Non-Metallic Mineral Products Industries

351 Clay Products Manufacturers
352 Cement Manufacturers
353 Stone Products Manufacturers
354 Concrete Products Manufacturers
355 Ready-Mix Concrete Manufacturers
256 Glass and Glass Products Manufacturers
357 Abrasives Manufacturers
358 Lime Manufacturers
359 Miscellaneous Non-Metallic Mineral Products Industries

Major Group 18-Petroleum and Coal Products Industries

365 Petroleum Refineries
369 Miscellaneous Petroleum and Coal Products Industries

Major Group 19-Chemical and Chemical Products Industries

372 Manufacturers of Mixed Fertilizers
373 Manufacturers of Plastics and Synthetic Basins
374 Manufacturers of Pharmaceuticals and Medicines
375 Paint and Varnish Manufacturers
376 Manufacturers of Soap and Cleaning Compounds
377 Manufacturers of Toilet Preparations
378 Manufacturers of Industrial Chemicals
379 Miscellaneous Chemical Industries

Major Group 20-Miscellaneous Manufacturing Industries

391 Scientific and Professional Equipment Industries
392 Jewellery and Silverware Industry
393 Sporting Goods and Toy Industries
397 Signs and Displays Industry
399 Miscellaneous Manufacturing Industries,n.e.s.

Division 6-Construction Industry

Major Group 1-General Contractors

404 Building Construction
406 Highway, Bridge and Street Construction
409 Other Construction

Major Group 2-Special-Trade Contractors

421 Special-Trade Contractors

Division 7-Transportation, Communication and Other Utilities

Major Group 1-Transportation

501 Air Transport
502 Services Incidental to Air Transport
503 Railway Transport
504 Water Transport
505 Services Incidental to Water Transport
506 Moving and Storage, Used Goods, Uncrated
507 Other Truck Transport
508 Bus Transport, Interurban and Rural
509 Urban Transit Systems
512 Taxicab Operations
515 Pipeline Transport
516 Highway and Bridge Maintenance
517 Miscellaneous Services Incidental to Transport
519 Other Transportation

Major Group 2-Storage

524 Grain Elevators
527 Other Storage and Warehousing

Major Group 3-Communication

543 Radio and Television Broadcasting
544 Telephone Systems
545 Telegraph and Cable Systems
548 Post Office

Major Group 4-Electric Power, Gas and Water Utilities

572 Electric Power
574 Gas Distribution
576 Water Systems
579 Other Utilities

Division 8-Trade

Major Group 1-Wholesale Trade

602 Wholesalers of Farm Products
606 Wholesalers of Coal and Coke
608 Wholesalers of Petroleum Products
611 Wholesalers of Paper and Paper Products
612 Wholesalers of General Merchandise
614 Wholesalers of Food
612 Wholesalers of Tobacco Products
616 Wholesalers of Drugs and Toilet Preparations
617 Wholesalers of Apparel and Dry Goods
618 Wholesalers of Household Furniture and Furnishings
619 Wholesalers of Motor Vehicles and Accessories
621 Wholesalers of Electrical Machinery, Equipment and supplies
622 Wholesalers of Farm Machinery and Equipment
623 Wholesalers of Machinery and Equipment,n.e.s.
624 Wholesalers of Hardware, Plumbing and Heating Equipment
625 Wholesalers of Metal and Metal Products,n.e.s.
626 Wholesalers of Lumber and Building Materials
627 Wholesalers of Scrap and Waste Materials
629 Wholesalers,n.e.s.

Major Group 2-Retail Trade

631 Food Stores
642 General Merchandise Stores
652 Tire, Battery and Accessories Stores
654 Gasoline Service Stations
656 Motor Vehicle Dealers
658 Motor Vehicle Repair Shops
663 Shoe Stores
665 Men's Clothing Stores
667 Women's Clothing Stores
669 Clothing and Dry Goods Stores,n.e.s.
678 Hardware Stores
676 Household Furniture and Appliance Stores
678 Radio, Television and Electrical Appliances Repair Shops
681 Drug Stores
691 Book and Stationary Stores
692 Florists' Shops
694 Jewellery Stores
695 Watch and Jewellery Repair Shops

696 Liquor, Wine and Beer Stores
697 Tobacconists
699 Retail Stores,n.e.s.

Division 9-Finance, Insurance and Real Estate

Major Group 1-Finance Industries

701 BANKS AND Other Deposit Accepting Establishments
703 Other Credit Agencies
705 Security Brokers and Dealers (including Exchanges)
707 Investment and Holding Companies
715 Canadian Offices of Canadian-Incorporated Companies Classified as Non-Canadian

Major Group 2-Insurance Carriers

721 Insurance Carriers

Major Group 3-Insurance Agencies and Real Estate Industry

735 Insurance and Real Estate Agencies
737 Real Estate Operators

Division 10-Community, Business and Personal Service Industries

Major Group 1-Education and Related Services

801 Kindergardens and Nursery Schools
802 Elementary and Secondary Schools
803 Schools of Art and of the Performing Arts
804 Vocational Centers, Trade Schools and Business Colleges
805 Post-Secondary Non-University Educational Institutions
806 Universities and Colleges
807 Libraries, Museums and Other Repositories
809 Education and Related Services,n.e.s.

Major Group 2-Health and Welfare Services

821 Hospitals
822 Related Health Care Institutions
823 Offices of Physicians and Surgeons
824 Offices of Para-medical Personnel (Practitioners)
825 Offices of Dentists
826 Diagnostic and Therapeutic Services,n.e.s.
827 Miscellaneous Health Services
828 Welfare Organizations

Major Group 3-Religious Organizations

831 Religious Organizations

Major Group 4-Amusement and Recreation Services

841 Motion Picture Theatres
842 Motion Picture Production and Distribution
843 Bowling Alleys and Billiard Parlours
844 Golf Clubs and Country Clubs
845 Theatrical and Other Staged Entertainment Services
849 Miscellaneous Amusement and Recreation Services

Major Group 5-Services to Business Management

851 Employment Agencies and Personnel Suppliers
853 Computer Services
855 Security and Investigation Services
856 Offices of Accountants
857 Advertising Services
863 Offices of Architects
864 Engineering and Scientific Services
866 Offices of Lawyers and Notaries
867 Offices of Management and Business Consultants
869 Miscellaneous Services to Business Management

Major Group 6-Personal Services

871 Shoe Repair Shops
872 Barber and Beauty Shops
873 Private Households

874 Laundries, Cleaners and Pressers(except Self-Service)
876 Self-Service Laundries and Dry Cleaners
877 Funeral Services
879 Miscellaneous Personal Services

Major Group 7-Accommodation and Food Services

881 Hotels and Motels
883 Lodging Houses and Residential Clubs
884 Camping Grounds and Trailer Parks
886 Restaurants, Caterers and Taverns

Major Group 8-Miscellaneous Services

891 Labour Organizations and Trade Associations
893 Photographic Services,n.e.s.
894 Automobile and Truck Rental
895 Machinery and Equipment Rental
896 Blacsmithing and Welding Shops
897 Miscellaneous Repair Shops
898 Services to Buildings and Dwellings
899 Miscellaneous Services,n.e.s.

Division 11-Public Administration and Defence

Major Group 1-Federal Administration

902 Defence Services
909 Other Federal Administration

Major Group 2-Provincial Administration

931 Provincial Administration

Major Group 3-Local Administration

957 Local Administration

Major Group 4-Other Government Offices

991 Other Government Offices

Division 12–Industry Unspecified or Undefined

999 Canadian-Incorporated Companies Classified as Non-Canadian
000 Unspecified or Undefined

Appendix II

Support Letter Drafted by

The Alberta Minister of the Environment

DEPARTMENT OF ENVIRONMENT
OFFICE OF THE MINISTER
LEGISLATIVE BUILDING
EDMONTON

January, 1973

Dear Sir or Madam:

The Alberta Department of The Environment, which is charged with the administration and management of the province's water resources, is conducting a comprehensive survey of industrial water use in Alberta. This is part of an ongoing study which was initiated in 1968.

The enclosed industrial water use questionnaire, when completed by your firm, will assist in providing information to assess present levels of water use in the province and to project future water demands. It is not the intent to publish information by firm, but by industry only. One of the fundamental principles governing water management in Alberta is that the province's water resources will be managed so as to serve the best interests of all Albertans. A prerequisite for sound management is accurate, up-to-date information. In the interest of obtaining information in a reasonable time span, returns are requested within three weeks of receipt of the questionnaire.

If any of the questions require further clarification, please contact either Mr Fred Schulte (425-1130, ext. 232) or Mrs. Anke Seifried (425-1130, ext. 233) of this Department.

Your cooperation in this survey is appreciated.

Yours very truly,

W. J. Yurko, P. Eng.

Encls.

Appendix III

Generalized Questionnaire

INDUSTRIAL WATER USE 1972

Return to:

ALBERTA DEPARTMENT OF THE ENVIRONMENT
10040 - 104 Street
Edmonton, Alberta
T5J 0Z6

The Total quantity of water intake in this establishment during the entire year 1972 was: (Mark one space only)

Under 100,000 imperial gallons	__
100,000 to 500,000 imperial gallons	__
500,000 to 1 million imperial gallons	__
1 to 5 million imperial gallons	__
5 to 10 million imperial gallons	__
10 million imperial gallons or over	__

Appendix IV

Detailed Industrial Water Use

Questionnaire: Alberta, 1972

INDUSTRIAL WATER USE

1972

RETURN TO	ALBERTA DEPARTMENT OF THE ENVIRONMENT 10040 – 104 Street Edmonton, Alberta T5J 0Z6

Name of person we may contact regarding this report	Address (Number, street, city)	Postal code	Telephone No.	Extension

Signature	Title	Date

INSTRUCTIONS

GENERAL – Please report all quantities in imperial gallons. Do not report in gallons per minute or gallons per day.

If no water is used, treated, or discharged, report "None." If your records on water used are in cubic feet, convert to gallons (1 cubic foot equals 6.2 gallons). Reasonably accurate estimates are acceptable

If you are in charge of several plants, please request additional questionnaires from us and fill out one questionnaire per plant.

Item I – WATER INTAKE BY KIND AND SOURCE

1. List water supplied by a water system other than your own (whether municipally or privately owned).

2. through 4. List water obtained from your own water supply system

3. If you have more than one ground water system (well), please list total intake from them. Please list their locations under remarks.

Item II – WATER INTAKE BY PURPOSE

1. Process water is all water that comes directly in contact with products and/or materials, including water which is consumed in the manufacture of products.

2, 3, 5, and 6 – Self-explanatory

4. Include water which is used for cooling and condensing purposes in conjunction with the operation of process equipment, but which does not come in direct contact with products or materials

Item III – WATER RECIRCULATED AND REUSED BY PURPOSE

If no water was recirculated or reused, mark "No" on line 1 and skip to item IV

If you recirculated or reused water, mark "Yes" on line 1 and report on lines 2 through 7 the estimated quantity of water that would have been required if no water had been recirculated or reused. For example if total water intake (item I) was 400 million gallons and of this 400 million gallons, 100 million gallons were used twice for cooling purposes and once for washing products or materials, the total water required would be 300 million gallons (less consumption and evaporation loss), plus the 300 million gallons not recirculated, for a total of 600 million gallons Distribute this total (600 million) by the purposes for which it was used

Item IV – WATER DISCHARGED BY POINT OF DISCHARGE

Include all water brought to ultimate discharge point whether treated or not. Do not include water held in your ponds, lagoons, or basins, for reuse or treatment, until actually discharged Do not report water evaporated or otherwise consumed and not brought to ultimate discharge point.

1. Report water discharged to public utility sewer systems, whether municipally or privately owned

2. – Self-explanatory

3. Include seepage into ground from your holding ponds, lagoons, etc (Note – If water is transferred to an agricultural establishment for spray irrigation, report such quantity on line 4).

4. Include transfers, after your own use, to another establishment of either your company or another company.

Item VII – WATER TREATED BY METHOD OF TREATMENT

Where requested report total quantity of water treated for –
- Control of biological growth
- Removal of suspended or dissolved solids
- Corrosion control.
- Any other purpose by simple or complex methods

Your remarks would be appreciated

ITEM I WATER INTAKE BY KIND AND SOURCE 1972	Name or Location	Imperial Gallons for the Year	CODE
1 Public (municipal) water system	150 Name		120
2 Company surface water system, such as streams or lakes	570 Name		130
3. Company ground water systems such as wells	172 Location Sec.Twp.Rge.Mer.		140
4 TOTAL *(Sum of lines 1 through 3*			460

ITEM II WATER INTAKE BY PURPOSE 1972		
1 Process		220
2 Cooling and Condensing – For steam electric power generation		228
3 – For air conditioning		236
4 – For other cooling and condensing		246
5 Boiler makeup		254
6 Sanitary service and other uses		262
7 TOTAL *(Sum of lines 1 through 6 should equal item 1 line 4*		270

ITEM III WATER RECIRCULATED OR REUSED BY PURPOSE 1972		
1 Was any water recirculated or reused? ☐ No If "No" mark "No" and skip to item IV	☐ Yes	170
2 Process		820
3 Cooling and Condensing – For steam electric power generation		828
4 – For air conditioning		838
5 – For other cooling and condensing		846
6 Boiler makeup		854
7 Sanitary service and other uses		862
8 TOTAL *(Sum of lines 2 through 7)*		870

ITEM IV WATER DISCHARGED BY POINT OF DISCHARGE 1972		
1 Public (municipal) utility sewer		520
2 Surface water body, such as stream, lake, etc. 560 Name		530
3 Ground (wells, spray, seepage, etc		540
4 Transferred to other users for reuse		550
5. TOTAL *(Sum of lines 1 through 4)*		760

ITEM V MONTHLY TOTALS 1972

	Imperial Gallons for each month							
	January	CODE	February	CODE	March	CODE	April	CODE
1. Water Intake		320		325		330		335
2. Water discharged		620		625		630		635
	May		June		July		August	
1. Water Intake		340		345		350		355
2. Water discharged		640		645		650		655
	September		October		November		December	
1. Water Intake		360		365		370		375
2. Water discharged		660		665		670		675

ITEM VI YEARLY TOTALS 1968 TO 1971

	Imperial Gallons for each year							
	1968		1969		1970		1971	
1. Water Intake		420		430		440		450
2. Water discharged		720		730		740		750

ITEM VII WATER TREATED BY METHOD OF TREATMENT 1972

A. INTAKEWATER

Intake water (included in item I) treated prior to use.
Exclude water treated only by chlorination.

1. *(Mark one)* 161 ☐ None treated ☐ Some treated

2. If some water was treated, enter quantity treated (gallons).

162
920 ☐

3. Report quantities treated by method of treatment.[1]

Method of treatment	Imperial Gallons for the year	163
Aeration		928
Coagulation		932
Filtration		938
Softening		944
Ion exchange		950
Corrosion control		956
pH		[illegible]2
Settling		968
Other *(Specify)*		974

B WATER RECIRCULATED

Water (included in item III) treated prior to recirc[illegible] or reuse

1. *(Mark one)* 164 ☐ None treated ☐ Some treated

2. If some water was treated, enter quantity treated [illegible] gallons

165
1020 ☐

3. Report quantities treated by me[illegible] quantities are unknown circle the method(s) of treatment or[illegible]

Method of treatment	Imperial Gallons for the year	166
Aeration		1026
Coagulation		1032
Filtration		103[illegible]
Softening		1044
Ion exchange		1050
Corrosion control		105[illegible]
pH		1062
Settling		[illegible]
Flotation		1074
Other *(Specify)*		112

C WATER DISCHARGED

Water (included in item IV) treated prior to discharge.

1. *(Mark one)* 167 ☐ None treated ☐ Some treated

2. If some water was treated, enter quantity treated (gallons). 168 1126 ☐

3. Report quantities treated by method of treatment.[3]

Method of treatment	Imperial Gallons for the year	169
Coagulation		1132
Primary settling		1138
Secondary settling		1144
Trickling filters		1150
Activated sludge		1156
Digestion (waste water, sludges etc.)		1162
Ponds or lagoons		1168
pH		1174
Sand filtration		1220
Chlorination		1226
Flotation		1232
Other *(Specify)*		1238

Footnotes:

1 When more than one method of treatment is reported, the sum of the quantities reported may add to more than the quantity reported in item VII A2

2 When more than one method of treatment is reported, the sum of the quantities reported may add to more than the quantity reported in item VII B2

3 When more than one method of treatment is reported, the sum of the quantities reported may add to more than the quantity reported in item VII C2

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Appendix V

Development and Use of
Input-Output Analysis in
Industrial Water Demand Estimation.

INPUT-OUTPUT ANALYSIS: BASIC ELEMENTS

Historical Development

Input-output analysis, a research tool as it exists today, was not "invented" at one point in time but rather evolved over a number of years.[1] Possibly one of the first to consider inter-industry economics was Francois Quesnay. Writing in the mid 1700's, Quesnay held to a body of economic theory known as physiocracy. Those proposing this theory were influenced by the contemporary discovery of the circulation of the blood. They attempted to show that the self-perpetuating nature of the economy was due to the circular flow of wealth. As part of his duties as court physician to Louis XV, Quesnay constructed in 1759 his Tableau Economique. His tableau essentially divided the whole of society into three classes in order to present a hypothetical scenario of the transfer of products and money throughout the economy. The essentials of Quesnay's Tableau are presented in Table V-1.

One can observe from Table V-1 that for example, the value of Agriculture's expenditures annually was about 1500

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1. This section is based on: C. H. Davis, Economic Evaluation of Water: Part V, (Berkeley: University of California Press, 1968), page 9.

livres. Of this amount, 600 livres worth stayed within

Table V-1

AN INPUT-OUTPUT PRESENTATION
OF QUESNAY'S TABLEAU
(Livres)

	Purchasing Sector			
Producing Sector	Agriculture	Industry	Land	Total Output
Agriculture	600	600	300	1500
Industry	300	300	300	900
Land	600	0	0	600
Total Output	1500	900	600	3900

Agriculture itself as consumption by farmers, and for the replacement of feed, seed, and other forms of capital. The remaining 900 livres worth of purchases were 300 livres to industry presumably for purchases of implements, and 600 livres to landlords as rent.

The Industrial sector on the other hand, has expenditures approximating 900 livres annually. Six hundred livres of the amount went to Agriculture while the remaining 300 livres stayed within the industrial sector itself. Landlord's (in the land sector) purchases amounted to about 600 livres. This amount was split evenly between the Agricultural and Industrial Sectors.

The physiocratic doctrine, then, led by Quesnay, was essentially a static view of the whole economy rather than a

partial dynamic analysis as employed by his predecessors.

It was some time before anyone else attempted to analyse the econcmy in a similar fashion to Quesney. Leon Walras was the next to take up the cause in his Elements D'economie Politique Pure in which he departed from the partial equilibrium approach of his contemporaries and focused his attention on general equilibrium. Walras' main thesis was that the unknown prices of goods and services could be determined under conditions of pure competttion in static equilibrium if one were given the following: 1. utility functions for each individual; 2. the individual demand and supply functions for each commodity; and 3. the technological relations of production. This type of analysis provided a broad overview of the economy but there were gross problems in obtaining the required data such that the system was of little practical value.

The one who put the capstone on intersectoral or interindustry relationships was Wassily Leontief. He essentially used the Walrasian system of static equilibrium with the properties of the equality of intersectoral demand and supply, free competition were prices equal average cost, and most importantly the fixity of technical coefficients. These coefficients imply that in any productive process all inputs are used in fixed proporations, regardless of the

level of output. The major change which Leontief made to the Walrasian system was that, in order to reduce the data gathering problem, he aggregated all industries in the economy into a relatively few sectors.

The Transactions or Flow Table

Fundamental to the Leontief system is the transactions or input- output table. Shown on such a table is how the output of each industry is distributed amongst other industries and sectors of the economy. Also, it shows from where the inputs for each industry or sector are derived. A hypothetical input-output table is shown in Table V-2.[1] An explanation of the input-output table is as follows. Each row (from left to right) shows the output sold by each industry or sector along the left-hand side of the table to each industry or sector across the top. Each column (from top to bottom) shows the purchases made by each industry or sector at the top of the table from the industries or sectors on the left. The Processing Sector in the upper left-hand corner of the table is composed of those industries producing goods and services. The Payments Sector, inclusive of rows 7 to 11, is to be read all the way

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1. This section is based on: W. H. Miernyk, Elements Of Input-Output Analysis, (New York: Random House, 1965), page 9.

Table V - 2

HYPOTHETICAL INPUT-OUTPUT TABLE

	Inputs	(1) A	(2) B	(3) C	(4) D	(5) E	(6) F	(7) Gross Inventory Accum - relation(+)	(8) Exports to Foreign Countries	(9) Gov't. Purchases	(10) Gross Private Capital Formation	(11) Households	(12) Total Gross Output
		Industry Purchasing: Purchasing Sector						Industry Purchasing: Final Demand					
Industry Producing: Processing Sector	(1) Industry A	10	15	1	2	5	6	2	5	1	3	14	64
	(2) Industry B	5	4	7	1	3	8	1	6	3	4	17	59
	(3) Industry C	7	2	8	1	5	3	2	3	1	3	5	40
	(4) Industry D	11	1	2	8	6	4	0	0	1	2	4	39
	(5) Industry E	4	0	1	14	3	2	1	2	1	3	9	40
	(6) Industry F	2	6	7	6	2	6	2	4	2	1	8	46
Industry Producing: Payments Sector	(7) Gross Inventory Depletion (-)	1	2	1	0	2	1	0	1	0	0	0	8
	(8) Inputs	2	1	3	0	3	2	0	0	0	0	2	13
	(9) Payments to Gov't.	2	3	2	2	1	2	3	2	1	2	12	32
	(10) Depreciation Allowances	1	2	1	0	1	0	0	0	0	0	0	5
	(11) Households	19	23	7	5	9	12	1	0	8	0	1	85
	(12) Total Gross Outlays	69	59	40	39	40	46	12	23	18	18	72	431

across the table and is composed of:

(a) Gross inventory depletion. This is simply the using up during the period of previously accumulated stocks of raw materials, intermediate goods, or finished products.

(b) Imports. This shows the value of imports by each sector or industry.

(c) Payments to Government. These take the form of taxes, or purchases of government services.

(d) Depreciation Allowances. These figures are approximately equal to the cost of plant and equipment used up in the production of the goods represented by the table.

(e) Households. Included here are wages, salaries, interest, and such payments made by the industries or sectors across the top to households.

The Final Demand Sector, in the upper right-hand section of the table, is unique in that changes which occur here are transmitted through the rest of the table. In general terms, its components are:

(a) Gross inventory accumulation. This column represents additions to inventories by each of the industries or sectors on the left-hand side of the table.

(b) Exports. In this column are the values of the exports during the period.

(c) Government Purchases. These are purchases made by all levels of Government.

(d) Gross private capital formation. These purchases are made in order to replace or add to plant and equipment.

(e) Households. This column represents the purchases by households of final goods and services from industries or sectors on the left-hand side of the table.

The Final Demand Sector is essentially the output of the processing sector which is sold outside the processing sector to income recipients.

The <u>Total Gross Outlay</u> row is a summation of the purchases made by the industries or sectors at the top of the table while <u>Total Gross Output</u> is simply a summation of the sales by the industries or sectors on the left to those on the top of the table. From the point of view of these two portions of the table, it is essential that all entries in the table be in value figures. Summations are meaningful in value not physical terms. The values used are generally producers' prices. The input-output table, then, adopts the double-entry bookkeeping technique.

The Gross National Product (GNP) can be determined from the input-output table for a nation. GNP measures only the <u>final</u> transactions of an economy. This is done in order to avoid double counting. Hence, if one were to omit the intermediate transactions (rows and columns 1 through 6 in Table V-2) the GNP would be 253 money units rather than 431.

The model just described is "open" as opposed to a

"closed" one. A completely closed input-output system is one in which there exists no exogenous sectors in the model. That is, the sectors which commonly appear as final demand columns are incorporated into the processing matrix. For example, "households" could be regarded as an industry purchasing output from the other sectors in return for labor services provided. The other components of final demand could be thought of in the same way.

There is a problem which arises from the all-encompassing, completely closed input-output system. Not all sectors of the economy have their transactions based on technical relationships with other sectors. For all levels of government, for example, the factors determining their transactions are political rather than technical in nature. Likewise exports are dependent on nontechnical factors and as such are placed outside of the processing sector. Similar justification can be given for all sectors commonly found in the Final Demand Sector.

Table of Direct Coefficients

Once an input-output table has been constructed, a table of technical coefficients can be produced for the processing sector. Essentially each technical coefficient (a_{ij}) states the value of sector i's production required by

sector j for the latter to produce one dollars worth of output. The Gross Output sector must be adjusted by subtracting inventory depletion to obtain adjusted gross output values. Once this has been accomplished the technical coefficient is determined by simply dividing all the entries in each industry's column by the adjusted gross output for that industry. Table 3 shows the technical coefficients for the model being discussed. The entries in Table V-3 are also

Table V-3

TABLE OF TECHNICAL COEFFICIENTS

Industries Purchasing

	A	B	C	D	E	F
A	.16	.26	.03	.05	.13	.13
B	.08	.07	.18	.03	.08	.18
C	.11	.04	.21	.03	.13	.07
D	.17	.02	.05	.21	.16	.09
E	.06	0	.03	.36	.08	.04
F	.03	.11	.18	.15	.05	.13

called the "Direct Purchases per Dollar of Output". The monetary units could be dropped and the coefficients regarded in percentage terms. Table V-3 states that if sector F decides to increase its production by $100,000, then, in order to affect this increase, it must purchase directly from industries A, B, C, D, and of its own product respectively thirteen, eighteen, seven, nine, four, and thirteen thousand dollars' worth of output. The total

increase in the value of these direct inputs resulting from the $100,000 increase in sector F's output is $64,000.

Certain stability conditions are required of the table of direct coefficients. These conditions require that at least one column in the table add up to less than unity and that no column in the table add to more than unity. The proof of these conditions is complex and beyond the scope of this thesis.

Table of Direct and Indirect Requirements

There are indirect as well as direct affects from an increase in the output of an industry. The direct affects can be thought of as the first round in a series. Since the output of industries A through F have increased due to the increase in industry F's output, so must their purchases have increased to bring about this required increase in output. This is round two. These rounds could go on to infinity.

Rather than adding up these "rounds" to infinity, there is a more simple, alternative method. This involves taking the difference between an identity matrix and the technical coefficients matrix and deriving a transposed inverse matrix. The resulting matrix, called the "inverted Leontief matrix", shows the total requirements both direct and

indirect per dollar of delivery outside the processing sector, ie to final demand. The result is Table V-4. Each

Table V-4

DIRECT AND INDIRECT REQUIREMENTS
PER DOLLAR OF FINAL DEMAND

	A	B	C	D	E	F
A	1.38	.25	.28	.41	.27	.23
B	.45	1.21	.16	.19	.12	.24
C	.27	.38	1.38	.23	.17	.39
D	.35	.25	.25	1.53	.65	.41
E	.35	.26	.31	.39	1.28	.25
F	.38	.35	.22	.30	.21	1.32

time industry F sells an additional dollars worth of output to a member of the final demand sector, the output of industries A, B, C, etc. increases by $0.38, $0.35, $0.22, etc.

As with the Table of Direct Coefficients, the Table of Direct and Indirect Coefficients must satisfy certain stability conditions. The fundamental stability condition, known as the "Hawkins-Simon condition" is that there be no negative entries in the Table of Direct and Indirect Requirements. If there were a negative entry, it would mean essentially that each time the "negative" industry increased its sales to final demand, the direct and indirect requirements needed for this increased output would decrease. This is not realistic.

Basic Assumptions of Input-Output

The Leontief model is really a description of a production function simplified sufficiently to make the model usable empirically. In addition to the Walrasian assumptions regarding static equilibrium and pure competition, the special asumptions which aid in this simplicity are: 1) Each commodity is produced by a single sector; 2) There are no externalities; 3) The production function is linear; and 4) Technology is constant.
These assumptions have been discussed at great length.[1] It is beyond the scope of this thesis to carry on a similar discussion.

Multiplier or Impact Analysis

One type of multiplier is the simple sectoral multiplier. This multiplier shows the total direct and indirect effect on gross output of an increase in final demand in an industry. This multiplier is determined by summing the entries in the respective column of $(I-A)^{-1}$ representing the sector with increased final demand.

Income multipliers are determined in a slightly

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1. For example see: H. C. Davis, op.cit., page 20.

different fashion. The household sector is inserted into the processing sector from the payments and final demand sectors. New tables of both direct, and indirect requirements are formed in the same way as mentioned earlier. Two kinds of income multipliers result: a "simple" income multiplier and a "full" income multiplier. The simple income multiplier is a measure of the direct and indirect effects on income of a change in final demand. The full income multiplier in addition measures the induced income effects.

Linkage Effects

The backward and forward linkages in an industry can be measured by use of input-output analysis. Very briefly, backward linkages for an industry are determined by finding the ratio of interindustry purchases to total production for that industry while foreward linkages are given by the ratio of interindustry sales to total production.

Forecasting

The other major use of I-O analysis is that of forecasting. Given the inverse of the Leontief matrix, and a vector of final demand, one can forecast the gross output required to meet that final demand. Let X be the gross

output required, $(I-A)^{-1}$ the inverted Leontief matrix, and Y a vector of final demand. If one were to project a vector of final demand, say for the year 1980, and assumed that the $(I-A)^{-1}$ matrix was constant, one could determine the vector of gross output required to meet that final demand by:

$$X_{1980} = (I-A)^{-1} Y$$

An extension of this property of input-output analysis, and the one which this paper is all about, is that of forecasting primary input requirements. Take the example of estimating the demand for water in industry. Suppose that, as above, there were a vector X_{1980} already in existance. Suppose further that one had to determine the quantity of water required in 1980 by industry to meet the requirements of Y . How would one go about the task?

The salient factor in estimating industrial water demands by the use of input-output techniques is that of the water-use coefficient. This coefficient, usually in physical terms, states the number acre-feet (or gallons etc.) of water necessary in the industrial process to produce a certain value (in dollars) of output. These coefficients will appear as a row vector (W) in the third quadrant of the transactions table. Therefore, the total amount of water required (W) can be determined by (method 1):

$$W_{1980} = w\ X_{1980}$$

An alternative method of performing this estimation uses a diagonal matrix, rather than a row vector of water-use coefficient. It also used a summation vector (method 2). Both methods will be demonstrated in the following section.

AN EMPERICAL EXAMPLE

The Input-Output Table

For purposes of this study, an aggregated form of the 1962 Alberta Input-Output Table will be used.[1] The complete input-output table contains the dissaggregated components of the Mining and Manufacturing industries. Again, the aggregated version of this table is used solely for demonstrating how one might use input-output analysis to forecast industrial water demands. The consolidated input-output table is shown in Table V-5. The unbracketted numbers represent values of transactions in thousands of dollars at producer's prices. The numbers in brackets are the direct requirement coefficients (the A matrix). Table V-6 is the table of direct and indirect requirements per dollar of final demand.

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1. R. Wright, The Alberta Economy: An Input-Output Analysis, (Calgary: University, of Calgary, 1962).

Table V - 5

CONSOLIDATED WRIGHT INPUT/OUTPUT TABLE, TRANSACTIONS AND TECHNOLOGICAL MATRICES

	1	2	3	4	5	6	7	Intermediate Demand =Wi	Final Demand =Yi	Total Use
1. Agriculture/Forestry	91,276 (.1465	222 (.0004)	268,627 (.6023)	15,800 (.0271)	1,167 (.0014)	0 (0)	267 (.0002)	377,359	245,598	622,957
2. Mining	1,225 (.0020)	9,888 (.0161)	2,230 (.0050)	87,686 (.1501)	14,837 (.0182)	3,805 (.0076)	10,572 (.0075)	130,243	485,375	615,618
3. Food Process	21,749 (.0349)	2,003 (.0033)	30,539 (.0685)	776 (.0013)	1,302 (.0016)	968 (.0019)	0 (0)	57,337	512,583	569,920
4. Other Manufacturing	38,716 (.0621)	25,497 (.0414)	6,355 (.0142)	84,433 (.1446)	135,502 (.1666)	69,019 (.1377)	21,405 (.0151)	380,927	946,398	1,327,325
5. Construction	10,365 (.0166)	10,369 (.0168)	4,007 (.0090)	6,237 (.0107)	478 (.0006)	17,134 (.0342)	6,637 (.0047)	55,227	757,980	813,207
6. Transportation, Communication	67,716 (.1087)	64,779 (.1052)	22,237 (.0499)	58,155 (.0996)	81,295 (.1000)	21,746 (.0434)	94,375 (.0667)	410,303	90,963	501,266
7. Utilities, Services	7.665 (.0123)	48,022 (.0780)	22,376 (.0502)	37,243 (.0638)	31,241 (.0384)	70,450 (.1405)	49,634 (.0351)	266,631	1,147,877	1,414,508
Uj=Produced Input	238,712 (.3832)	160,780 (.2612)	356,371 (.7991)	290,330 (.4971)	265,822 (.3269)	183,122 (.3653)	182,890 (.1293)			
Mj=Imported Input	28,868 (.0463)	64,129 (.1042)	17,627 (.0395)	115,473 (.1977)	208,344 (.2562)	64,351 (.1284)	62,240 (.0440)			
Vj=Primary Input	355,377 (.5705)	390,709 (.6347)	71,967 (.1614)	178,226 (.3052)	339,041 (.4169)	253,793 (.5063)	1,169,378 (.8267)			
Xj=Total Product	622,957 (1.0000)	615,618 (1.0000)	445,965 (1.0000)	584,029 (1.0000)	813,207 (1.0000)	501,266 (1.0000)	1,414,508 (1.0000)			
Tj=Imports Into Final Demand	0 (0)	00 (0)	123,955 (.2779)	743,296 (1.2727)	0	0	0			
TOTAL USE	622,957	615,618	569,920	1,327,325	813,207	501,266	1,414,508			

Table V-6

CONSOLIDATED WRIGHT INPUT/OUTPUT TABLE - INVERSE MATRIX

	1	2	3	4	5	6	7
1. Agriculture Forestry	1.198	.004	.597	.016	.006	.004	.001
2. Mining	.012	1.023	.013	.074	.034	.022	.011
3. Food Processing	.035	.003	.844	.001	.002	.002	0
4. Manufacturing	.047	.031	.034	.477	.088	.074	.013
5. Construction	.026	.022	.023	.009	1.006	.039	.008
6. Transportation Commmunication	.15	.126	.124	.064	.124	1.071	.077
7. Utilities Services	.044	.104	.074	.047	.067	.164	1.050

Water-Use Coefficients

In order that this demonstration be completed hypothetical water-use coefficients will be used. Their value is not so much in their accuracy as in their ability to fulfill the purpose of this section. These coefficients are shown in Table 7.

Table V-7

HYPOTHETICAL WATER-USE COEFFICIENTS

Sector No.	Acre-feet per thousand (1972) dollars of output
1. Agriculture/Forestry	100
2. Mining	2
3. Food Processing	3
4. Manufacturing	7
5. Construction	3
6. Transportation/Communication	1
7. Utilities/Services	2

The Final Demand Vector

Again, for demonstration purposes, a hypothetical vector of final demand is used. This vector is presented in Table V-8.

Table V-8

HYPOTHETICAL FINAL DEMAND VECTOR, 1980

Sector No.	Final Demand Thousand (1972) Dollars
1	400,000
2	600,000
3	600,000
4	1,000,000
5	800,000
6	100,000
7	1,300,000

<u>Estimation of Water Requirements</u>

The first step in estimating the water requirements is that of determining the level of output (X) necessary to achieve the projected final demand. Again, this is achieved by:

$$X_{1980} = (I-A)^{-1} Y_{1980}$$

The X_{1980} vector is shown in Table V-9. Once the vector of

Table V-9

THE REQUIRED OUTPUT LEVEL

Sector No.	1980 Required level of output: Thousands (1972) Dollars
1	862,300
2	744,100
3	553,000
4	629,500
5	865,500
6	580,400
7	1,606,400

gross output is determined, the amount of water required is (estimated according to method 1) by:

$$W = w\ X$$

That is, W is the total amount of water required by all industries in order to deliver the projected final demands for each industry. The amount of water required by the first industry for example is given by:

$$W^1 = w^1\ X^1$$

The water requirements of industry one are about 86 billion

acre-feet while total requirements by all industries are about 100 billion acre-feet.

An alternative procedure (method 2) is available. The matrix of direct and indirect requirements per dollar of final demand is post multiplied by a diagonal matrix (D) consisting of water-use coefficients on the diagonal and zeros everywhere else. The resulting matrix is then post-multiplied by a summation vector (a column of ones) and the result shows the amount of water per dollar of final demand for each industry. By multiplying these numbers by the respective final demand estimates, one is able to project the amount of water needed by sector. According to this procedure the water requirements by industry and total for 1980 will be:

Sector No.	Water Requirements Acre-feet, 1980
1	86,230,000
2	1,488,200
3	1,106,000
4	4,406,500
5	2,596,500
6	580,400
7	3,212,800
Total	99,610,400

CONCLUSIONS

The major conclusion to be drawn from the foregoing is that input-output analysis is a useful tool for estimating industrial water demands. Inherent in its usefulness is the linking up of the demand for industrial water with the demand for the product of which it is a factor. Hence if the demand for the product changes , there will be a proportionate change in the use of all inputs, including water.

Input-output analysis, or interindustry analysis as it is sometimes called, has one other particularly useful element with regard to estimating industrial water demands. If the demand for the industry's output changes, the effect is felt not only directly but also indirectly through the series of 'rounds' resulting. Therefore input-output analysis aids one in accounting for both the direct and indirect requirements for water as a result of a change in final demand.

This type of analysis is of particular significance in Alberta. Since the price of the majority of industrial water approaches zero, demand estimations must be made using nonprice criteria. If one has some confidence in the input-output table used, and the water-use coefficients derived,

then industrial water demands based on this technique should yield meaningful results.

Appendix VI

Derivation of the Weighted Moving Average Formula.

Derivation of the Weighted Moving Average Formula.

Given industrial water demand data for periods 1,2,3, and 4, for example, that for the 5th period can be estimated as follows.[1]

Let:

WD^1 be the industrial water demand in period 1,

WD^2 be the industrial water demand in period 2,

WD^3 be the industrial water demand in period 3, and

WD^4 be the industrial water demand in period 4.

Also, let X be the long term average trend = $(WD^4-WD^1)/3$

Let Y be the more recent average trend = (WD^4-WD^3)

then,

$$\begin{aligned} WD^5 &= WD^4 + (X+Y)/2 \\ &= WD^4 + ((WD^4 - WD^1)/3 + (WD^4 - WD^3))/2 \\ &= WD^4 + (4WD^4 - 3WD^3 - WD^1)/6 \end{aligned}$$

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1. Alberta Department of Municipal Affairs, Population Trends, (Edmonton: Queens Printer), p. 1.

Appendix VII

Projected Water Demand:
Extrapolation Procedure,
Selected Industries,
Alberta, 1973-1980

Table VII-1

Projected Water Demand:

Food and Beverage Industry,

Alberta, 1973 to 1980.

('000 acre-feet)

Year	Water Demand
1973	27
1974	28
1975	29
1976	31
1977	32
1978	33
1979	35
1980	36

Table VII-2

Projected Water Demand:
Paper and Allied Industries,
Alberta, 1973-1980
('000 acre-feet)

Year	Water Demand
1973	30
1974	32
1975	33
1976	34
1977	35
1978	37
1979	38
1980	39

Table VII-3

Projected Water Demand:

Primary Metals Industry,

Alberta, 1973-1980

(acre-feet)

Year	Water Demand
1973	5280
1974	5490
1975	5700
1976	5910
1977	6150
1978	6360
1979	6780
1980	7020

Table VII-4

Projected Water Demand:
Oil Extraction Industry,
Alberta, 1973-1980
('000 acre-feet)

Year	Water Demand
1973	68
1974	74
1975	79
1976	85
1977	91
1978	96
1979	102
1980	108

Table VII-5

Projected Water Demand:

Non-Metallic Minerals Industry,

Alberta, 1973-1980

('000 acre-feet)

Year	Water Demand
1973	53
1974	55
1975	57
1976	59
1977	61
1978	63
1979	65
1980	67

Table VII-6

Projected Water Demand:

Petroleum Industry,

Alberta, 1973-1980

('000 acre-feet)

Year	Water Demand
1973	42
1974	43
1975	44
1976	46
1977	47
1978	49
1979	50
1980	51

Table VII-7

Projected Water Demand:

Chemical Industry,

Alberta, 1973-1980

('000 acre-feet)

Year	Water Demand
1973	72
1974	70
1975	68
1976	66
1977	64
1978	63
1979	60
1980	58

Appendix VIII

Tabulated Industrial Water Demand

Survey Results: Two-

And Three-Digit Industries.

Alberta, 1972.

TABLE VIII - 1

LOCATION OF MAJOR USING FIRMS
TWO-DIGIT INDUSTRIES, BY URBAN CENTER
ALBERTA, 1972

(NUMBER OF FIRMS)

INDUSTRY	URBAN CENTER								
	EDMONTON	CALGARY	LETHBRIDGE	MEDICINE HAT	GRANDE PRAIRIE	PEACE RIVER	RED DEER	OTHER	TOTAL
FOOD AND BEVERAGE	31	28	18	5	4	1	10	15	112
RUBBER AND PLACTICS PRODUCTS	3	4		1					8
LEATHER	2								2
CLOTHING	1								1
WOOD INDUSTRIES	2	2			1			3	8
FURNITURE		1							1
PAPER	2	6						3	11
PRINTING		3							3
PRIMARY METAL	3	7		1				2	13
METAL FABRICATING	7	6							13
MACHINERY		1							1
TRANS. EQUIP.	2	2							4
ELECTRICAL PRODUCTS		4	1						5
PETROLEUM	4	3						2	9
CHEMICAL	10	5		1				6	22
MISCELLANEOUS MANU-FACTURERS	2								2
MINERAL FUELS	1	5						133	139
QUARRIES AND SAND PITS	2	5			1			5	13
NON-METALLIC MINERAL	13	12	5	3	2	1	1	18	55
TOTAL	85	94	24	11	8	2	11	187	422

TABLE V111 - 2

LOCATION OF MAJOR WATER-USING FIRMS
SELECTED THREE-DIGIT INDUSTRIES, BY URBAN CENTER
ALBERTA, 1972

(NUMBER OF FIRMS)

INDUSTRY	RIVER BASIN								TOTAL
	EDMONTON	CALGARY	LETHBRIDGE	MEDICINE HAT	GRANDE PRAIRIE	PEACE RIVER	RED DEER	OTHER	
COAL MINES	1							5	6
NATURAL GAS		5						62	67
OIL WELLS								66	66
MEAT AND POULTRY	10	9	6	2	1		4		32
FRUIT AND VEGETABLE	1		2					2	5
DAIRY PRODUCTS	6	4	2	1	1	1	3	7	25
FLOUR AND BREAKFAST CEREAL		2		1				1	4
FEED INDUSTRY	1	1	1				1		4
BAKERY PRODUCTS	4	2							6
MISCELLANEOUS FOOD	1	1	3					4	9
BEVERAGE	8	9	4	1	2		2	1	27
CLAY PRODUCTS	1		1	2				2	6
CEMENT	1							2	3
CONCRETE	7	7	2						16
READY MIX	3	4	1	1	2	1	1	11	24
GLASS	1							2	3
LIME			1					1	2
MISCELLANEOUS MANUFACTURING		1							1
TOTAL	45	45	23	8	6	2	11	166	306

TABLE VIII - 3

LOCATION OF MINOR WATER USING FIRMS
TWO-DIGIT INDUSTRIES, BY URBAN CENTER
ALBERTA,

(Number of Firms)

INDUSTRY	URBAN CENTER								TOTAL
	EDMONTON	CALGARY	LETHBRIDGE	MEDICINE HAT	GRANDE PRAIRIE	PEACE RIVER	RED DEER	OTHER	
FOOD AND BEVERAGE	1	1	1	1	1		1	4	10
RUBBER AND PLASTICS PRODUCTS		1						2	4
LEATHER	1	1					1	3	6
CLOTHING	1	1							2
WOOD INDUSTRIES	1	1	1	1	1		1	4	10
FURNITURE	1	1	1	1				2	6
PAPER	1	1						2	4
PRINTING	1	1	1	1	1		1	4	10
PRIMARY METAL	1	1	1					2	5
METAL FABRICATING	1	1	1	1	1		1	4	10
MACHINERY	1	1	1				1	2	6
TRANS. EQUIP.	1	1	1	1			1	3	8
ELECTRICAL PRODUCTS	1	1						2	4
PETROLEUM	1	1						1	3
CHEMICAL	1	1						1	3
MISCELLANEOUS MANUFACTURERS	1	1	1	1	1		1	4	10
MINERAL FUELS									
QUARRIES AND SAND PITS									
NON-METALLIC MINERAL	1	1	1	1			1	3	8
TOTAL	18	18	11	8	5	-	9	44	113

TABLE VIII - 4

LOCATION OF MAJOR WATER USING FIRMS
TWO-DIGIT INDUSTRIES, BY RIVER BASIN
ALBERTA, 1972

(NUMBER OF FIRMS)

INDUSTRY	RIVER BASIN					TOTAL
	PEACE RIVER	ATHABASCA	NORTH SASK.	RED DEER	SOUTH SASK.	
FOOD AND BEVERAGE	5		38	11	58	112
RUBBER AND PLASTICS PRODUCTS			3		5	8
LEATHER			2			2
CLOTHING			1			1
WOOD INDUSTRIES	1	1	2		4	8
FURNITURE					1	1
PAPER		1	4		6	11
PRINTING					3	3
PRIMARY METAL			5		8	13
METAL FABRICATING			7		6	13
MACHINERY					1	1
TRANS. EQUIP.			2		2	4
ELECTRICAL PRODUCTS					5	5
NON-METALLIC MINERAL	4		20	2	29	55
PETROLEUM			5	1	3	9
CHEMICAL			16		6	22
MISCELLANEOUS MANUFACTURERS			2			2
MINERAL FUELS	17	27	30	31	34	139
QUARRIES AND SAND PITS	1		5		7	13
TOTAL	28	29	142	45	178	442

TABLE V111 - 5

LOCATION OF MAJOR WATER-USING FIRMS
SELECTED THREE-DIGIT INDUSTRIES, BY RIVER BASIN
ALBERTA, 1972

(NUMBER OF FIRMS)

INDUSTRY	RIVER BASIN					TOTAL
	PEACE RIVER	ATHABASCA	NORTH SASK.	RED DEER	SOUTH SASK.	
COAL MINES	2			1	3	6
NATURAL GAS	10	11	10	18	18	67
OIL WELLS	5	16	20	12	13	66
MEAT AND POULTRY	1		10	4	17	32
FRUIT AND VEGETABLE			1		4	5
DAIRY PRODUCTS	2		11	4	8	25
FLOUR AND BREAKFAST CEREAL			1		3	4
FEED INDUSTRY			1	1	2	4
BAKERY PRODUCTS			4		2	6
MISCELLANEOUS FOOD			1		8	9
BEVERAGE	2		9	2	14	27
CLAY PRODUCTS			1		5	6
CEMENT			2		1	3
CONCRETE			7		9	16
READY MIX	4		8	2	10	24
GLASS			2		1	3
LIME					2	2
MISCELLANEOUS MANUFACTURING					1	1
TOTAL	26	27	88	44	121	306

TABLE V111 - 6

LOCATION OF MINOR WATER-USING FIRMS
TWO-DIGIT INDUSTRIES, BY RIVER BASIN
ALBERTA, 1972

(Number of Firms)

INDUSTRY	RIVER BASIN					TOTAL
	PEACE RIVER	ATHABASCA	NORTH SASK.	RED DEER	SOUTH SASK.	
FOOD AND BEVERAGE	2		2	2	4	10
RUBBER AND PLASTICS PRODUCTS			2		2	4
LEATHER			2	2	2	6
CLOTHING			1		3	4
WOOD INDUSTRIES	2		2	2	4	10
FURNITURE			2		4	6
PAPER			2		2	4
PRINTING	2		2	2	4	10
PRIMARY METAL			2		3	5
METAL FABRICATING	2		2	2	4	10
MACHINERY			2	1	3	6
TRANS. EQUIP.			2	2	4	8
ELECTRICAL PRODUCTS			2		2	4
PETROLEUM			2		1	3
CHEMICAL			1		2	3
MISCELLANEOUS MANUFACTURERS	2		2	2	4	10
TEXTILES			1		3	4
QUARRIES AND SAND PITS						
NON-METALLIC MINERAL			2	2	4	8
TOTAL	10	-	33	17	53	113

TABLE VIII - 7

WATER INTAKE BY MAJOR FIRMS
TWO-DIGIT INDUSTRIES, BY URBAN CENTER
ALBERTA, 1972

(ACRE - FEET)

INDUSTRY	URBAN CENTER								TOTAL
	EDMONTON	CALGARY	LETHBRIDGE	MEDICINE HAT	GRANDE PRAIRIE	PEACE RIVER	RED DEER	OTHER	
FOOD AND BEVERAGE	5973	7006	2438	825	68	11	888	5020	22229
RUBBER AND PLASTICS PRODUCTS	39	856		249					1144
LEATHER	153								153
CLOTHING	14								14
WOOD INDUSTRIES	54	13			60			54	189
FURNITURE		6							6
PAPER	480	747						29280	30507
PRINTING		60							60
PRIMARY METAL	243	350		6				3943	4542
METAL FABRICATING	63	90							153
MACHINERY		85							85
TRANS. EQUIP.	62	322							384
ELECTRICAL PROD.		300	10						310
NON-METALLIC MINERAL	768	1776	328	47	5	1	2	1308	4239
PETROLEUM	7456	25686						229	33371
CHEMICAL	11530	50185		2637				6760	71,112
MISCELLANEOUS MANUFAC-TURERS	190								190
MINERAL FUELS	84	610						100617	101011
QUARRIES AND SAND PITS	2	5			1			5	12
TOTAL	27111	88097	2776	3764	134	12	890	147216	269799

TABLE V111 - 8

WATER INTAKE BY MAJOR FIRMS
SELECTED THREE-DIGIT INDUSTRIES, BY URBAN CENTER
ALBERTA, 1972

(Acre - Feet)

INDUSTRY	URBAN CENTER								TOTAL
	EDMONTON	CALGARY	LETHBRIDGE	MEDICINE HAT	GRANDE PRAIRIE	PEACE RIVER	RED DEER	OTHER	
COAL MINES	84							1932	2016
NATURAL GAS		610						41217	41,827
OIL WELLS								57169	57169
MEAT AND POULTRY	3576	3472	1098	620	33		542		9341
FRUIT AND VEGETABLE	15		504					416	935
DAIRY PRODUCTS	420	448	110	47	11	11	306	104	1457
FLOUR AND BREAKFAST CEREAL		30		8				3	41
FEED INDUSTRY	551	6	11				29		397
BAKERY PRODUCTS	72	22							94
MISCELLANEOUS FOOD	11	76	255					4461	4803
BEVERAGE	1328	2952	460	150	24		18	29	4961
CLAY PRODUCTS	2		2	44				29	77
CEMENT	435							867	1302
CONCRETE	175	91	310						576
READY MIX	30	1621	6	3	5	1	2	92	1760
GLASS	126							28	154
LIME			10					396	406
MISCELLANEOUS MANUFACTURING	.	64							64
TOTAL	6825	9392	2766	872	73	12	897	106743	127580

TABLE VIII - 9

WATER INTAKE BY MINOR FIRMS
TWO-DIGIT INDUSTRIES, BY URBAN CENTER
ALBERTA, 1972

(ACRE - FEET)

INDUSTRY	URBAN CENTER								TOTAL
	EDMONTON	CALGARY	LETHBRIDGE	MEDICINE HAT	GRANDE PRAIRIE	PEACE RIVER	RED DEER	OTHER	
FOOD AND BEVERAGE	41	60	17	7	2		7	244	378
RUBBER AND PLASTICS	11	11						2	24
LEATHER	2	1					1	6	10
CLOTHING	8	4							12
WOOD INDUSTRIES	8	10	1	1	5		1	36	62
FURNITURE	28	17	1	1				6	53
PAPER	1	1						28	30
PRINTING	15	25	2	1	1		2	28	74
PRIMARY METAL	1	1	1					3	6
METAL FABRICATING	65	48	6	2	1		1	68	191
MACHINERY	14	2	1				1	10	28
TRANS. EQUIP.	9	9	5	1			3	21	48
ELECTRICAL PROD.	7	8						3	18
NON-METALLIC MINERAL	29	15	4	2			1	74	120
PETROLEUM	2	3						2	7
CHEMICAL	5	12						1	18
MISC. MANUFAC.	27	23	2	1	2		1	13	69
TEXTILES	2	7	1					2	12
QUARRIES AND SAND PITS									
TOTAL	270	257	41	16	11		18	547	1160

TABLE V111 - 10

WATER INTAKE BY MAJOR FIRMS
TWO-DIGIT INDUSTRIES, BY RIVER BASIN
ALBERTA, 1972

(ACRE - FEET)

INDUSTRY	RIVER BASIN					TOTAL
	PEACE RIVER	ATHABASCA	NORTH SASK.	RED DEER	SOUTH SASK.	
FOOD AND BEVERAGE	79		6014	902	15234	22229
RUBBER AND PLASTICS			39		1105	1144
LEATHER			153			153
CLOTHING			14			14
WOOD INDUSTRIES	60	11	54		64	189
FURNITURE					6	6
PAPER		29277	516		774	30507
PRINTING					60	60
PRIMARY METAL			4190		352	4542
METAL FABRICATING			63		90	153
MACHINERY					85	85
TRANS. EQUIP.			62		322	384
ELECTRICAL PROD.					310	310
NON-METALLIC MINERAL	32		1227	8	3072	4339
PETROLEUM			7640	45	25686	33371
CHEMICAL			18288		52824	71112
MISCELLANEOUS MANUFACTURERS			190			190
MINERAL FUELS	11016	48497	29220	6984	5294	101011
QUARRIES AND SAND PITS	1		5		7	13
TOTAL	11188	77725	67675	7939	105278	269799

TABLE V111 - 11

WATER INTAKE BY MAJOR FIRMS
SELECTED THREE-DIGIT INDUSTRIES, BY RIVER BASIN
ALBERTA, 1972

(ACRE - FEET)

INDUSTRY	RIVER BASIN					TOTAL
	PEACE RIVER	ATHABASCA	NORTH SASK.	RED DEER	SOUTH SASK.	
COAL MINES	1826			1	189	2016
NATURAL GAS	6900	26257	660	4140	3870	41827
OIL WELLS	2290	22240	28560	2844	1235	57169
MEAT AND POULTRY	33		3510	536	5202	9341
FRUIT AND VEGETABLE			15		920	935
DAIRY PRODUCTS	22		539	320	576	1457
FLOUR AND BREAKFAST CEREAL			5		36	41
FEED INDUSTRY			551	28	18	597
BAKERY PRODUCTS			72		22	94
MISCELLANEOUS FOOD			11		4792	4803
BEVERAGE	24		1251	18	3668	4961
CLAY PRODUCTS			2		75	77
CEMENT			810		432	1302
CONCRETE			175		401	576
READY MIX	32		40	8	1680	1760
GLASS			140		14	154
LIME					406	406
MISCELLANEOUS MANUFACTURERS					64	64
TOTAL	11127	48497	36461	7895	23600	127580

TABLE VIII - 12

WATER INTAKE BY MINOR FIRMS
SELECTED THREE-DIGIT INDUSTRIES, BY RIVER BASIN
ALBERTA, 1972

(ACRE - FEET)

INDUSTRY	RIVER BASIN					TOTAL
	PEACE RIVER	ATHABASCA	NORTH SASK.	RED DEER	SOUTH SASK.	
FOOD AND BEVERAGE	7		114	19	238	378
RUBBER AND PLASTICS			12		12	24
LEATHER			5	2	3	10
TEXTILES			2		10	12
CLOTHING			8		4	12
WOOD INDUSTRIES	12		20	2	28	62
FURNITURE			33		20	53
PAPER			15		15	30
PRINTING	2		24	3	45	74
PRIMARY METAL			2		4	6
METAL FABRIC	2		101	2	86	191
MACHINERY			32	1	5	28
TRANS. EQUIP.			16	5	27	48
ELECTRICAL PROD.			8		10	118
NON-METALLIC MINERAL			62	3	55	120
PETROLEUM			4		3	7
CHEMICAL			5		13	18
MISCELLANEOUS MANUF.	3		33	2	31	69
TOTAL	26		486	39	609	1160

TABLE VIII - 13

SURFACE WATER INTAKE BY MAJOR FIRMS
TWO-DIGIT INDUSTRIES, BY RIVER BASIN
ALBERTA, 1972

(ACRE - FEET)

INDUSTRY	RIVER BASIN					TOTAL
	PEACE RIVER	ATHABASCA	NORTH SASK.	RED DEER	SOUTH SASK.	
FOOD AND BEVERAGE					337	3370
RUBBER AND PLASTICS						
LEATHER						
CLOTHING						
WOOD INDUSTRY						
FURNITURE						
PAPER		24217	174			24391
PRINTING						
PRIMARY METAL						
METAL FABRIC						
MACHINERY						
TRANS. EQUIP.						
ELECTRICAL PRODUCTS						
NON-METALLIC MINERAL					1554	1554
PETROLEUM			7347	17	25662	33026
CHEMICAL			16916		2637	19553
MISCELLANEOUS MANUFACTURERS						
QUARRIES AND SAND PITS			1		1	2
MINERAL FUELS	7750	47140	23955	4770	3679	87294
TOTAL	7750	71357	48393	4787	36903	169190

TABLE V111 - 14

SURFACE WATER INTAKE BY MAJOR FIRMS
SELECTED THREE-DIGIT INDUSTRIES BY RIVER BASIN
ALBERTA, 1972

(Acre - Feet)

INDUSTRY	RIVER BASIN					
	PEACE RIVER	ATHABASCA	NORTH SASK.	RED DEER	SOUTH SASK.	TOTAL
COAL MINES	1770				80	1850
NATURAL GAS	4000	26170	262	2634	2961	36027
OIL WELLS	1980	20970	23693	2136	638	49417
MEAT AND POULTRY						
FRUIT AND VEGETABLE					295	295
DAIRY PRODUCTS						
FLOUR AND BREAKFAST CEREAL						
FEED INDUSTRY						
BAKERY PRODUCTS						
MISCELLANEOUS FOOD					1968	1968
BEVERAGE					1107	1107
CLAY PRODUCTS						
CEMENT						
CONCRETE						
READY MIX					1554	1554
GLASS						
LIME						
MISCELLANEOUS MANUFACTURING						
TOTAL	7750	47140	23955	4770	8603	92218

TABLE V111 - 15

GROUND WATER INTAKE BY MAJOR FIRMS
TWO-DIGIT INDUSTRIES, BY RIVER BASIN
ALBERTA, 1972

(ACRE - FEET)

INDUSTRY	RIVER BASIN					TOTAL
	PEACE RIVER	ATHABASCA	NORTH SASK.	RED DEER	SOUTH SASK.	
FOOD AND BEVERAGE				56	3000	3056
RUBBER AND PALSTICS						
LEATHER						
CLOTHING						
WOOD INDUSTRY						
FURNITURE						
PAPER						
PRINTING						
PRIMARY METAL						
METAL FABRIC						
MACHINERY						
TRANS. EQUIP.						
ELECTRICAL PRODUCTS						
NON-METALLIC MINERAL			107		466	573
PETROLEUM			188	17		205
CHEMICAL			4		48926	48930
MINERAL FUELS	2568	1357	5166	1712	1342	12145
QUARRIES AND SAND PITS			2		1	3
TOTAL	2568	1357	5467	1785	53735	64912

TABLE V111 - 16

GROUND WATER INTAKE BY MAJOR FIRMS
SELECTED THREE-DIGIT INDUSTRIES, BY RIVER BASIN
ALBERTA, 1972

(ACRE - FEET)

INDUSTRY	RIVER BASIN					TOTAL
	PEACE RIVER	ATHABASCA	NORTH SASK.	RED DEER	SOUTH SASK.	
COAL MINES	55			1	30	86
NATURAL GAS	2208	90	306	1495	688	4787
OIL WELLS	305	1280	4860	216	624	7285
MEAT AND POULTRY				40	2544	2584
FRUIT AND VEGETABLE				14		14
DAIRY PRODUCTS					17	17
FLOUR AND BREAKFAST CEREAL					11	11
FEED INDUSTRY						
BAKERY PRODUCTS						
MISCELLANEOUS FOOD						
BEVERAGE					428	428
CLAY PRODUCTS						
CEMENT			77			77
READY MIX			30			30
GLASS					60	60
LIME						
MISCELLANEOUS MANUFACTURING					406	406
TOTAL	2568	1370	5273	1766	4808	15785

TABLE V111 - 17

MUNICIPAL WATER INTAKE BY MAJOR FIRMS
TWO-DIGIT INDUSTRIES, BY RIVER BASIN
ALBERTA, 1972

(Acre - Feet)

INDUSTRY	RIVER BASIN					TOTAL
	PEACE RIVER	ATHABASCA	NORTH SASK.	RED DEER	SOUTH SASK.	
FOOD AND BEVERAGE	79		6014	846	8864	15803
RUBBER AND PLASTICS PRO.			39		1105	1144
LEATHER			153			153
CLOTHING			14			14
WOOD INDUSTRY	600	11	54		64	189
FURNITURE					6	6
PAPER		5000	342		774	6116
PRINTING					60	60
PRIMARY METAL			4190		352	4542
METAL FABRIC			63		90	153
MACHINERY					85	85
TRANS. EQUIP.			62		322	384
ELECTRICAL PRODUCTS					310	310
NON-METALLIC MINERAL	32		1120	8	948	2108
PETROLEUM			105	11	24	140
CHEMICAL			1368		1261	2629
MISCELLANEOUS MANUFACTURING			190			190
QUARRIES AND SAND PITS	1		2		5	8
MINERAL FUELS	698		99	502	273	1572
TOTAL	861	5011	12252	1378	14311	33813

TABLE V111 - 18

MUNICIPAL WATER INTAKE BY MAJOR FIRMS
SELECTED THREE-DIGIT INDUSTRIES, BY RIVER BASIN
ALBERTA, 1972

(ACRE - FEET)

INDUSTRY	RIVER BASIN					TOTAL
	PEACE RIVER	ATHABASCA	NORTH SASK.	RED DEER	SOUTH SASK.	
COAL MINES	1				79	80
NATURAL GAS	692		92	11	221	1016
OIL WELLS	5		7	492		504
MEAT AND POULTRY	33		3570	496	2658	6757
FRUIT AND VEGETABLE			15		625	640
DAIRY PRODUCTS	22		539	306	576	1443
FLOUR AND BREAKFAST CEREAL			5		19	24
FEED INDUSTRY			551	28	7	586
BAKERY PRODUCTS			72		22	94
MISCELLANEOUS FOOD			11		2806	2817
BEVERAGE	24		1251	18	2133	3426
CLAY PRODUCTS			2		75	77
CEMENT			793		432	1225
CONCRETE			145		297	442
READY MIX	32		40	8	66	146
GLASS			140		14	154
LIME						
MISCELLANEOUS MANUFACTURING					64	64
TOTAL	809	-	7233	1359	10094	19495

TABLE V111 - 19

WATER RECIRCULATION BY MAJOR FIRM
TWO-DIGIT INDUSTRIES, BY URBAN CENTER
ALBERTA, 1972

(ACRE - FEET)

INDUSTRY	URBAN CENTER								TOTAL
	EDMONTON	CALGARY	LETHBRIDGE	MEDICINE HAT	GRANDE PRAIRIE	PEACE RIVER	RED DEER	OTHER	
FOOD AND BEVERAGE	9966	7132	4356	36			520	9012	31022
RUBBER AND PLASTICS PRODUCTS		2		224					226
LEATHER									
CLOTHING	3								3
WOOD INDUSTRIES	1330							55	1385
FURNITURE									
PAPER	7923	9						130	8062
PRINTING									
PRIMARY METAL	7525	1332						95273	104133
METAL FABRICATING	2585								2585
MACHINERY									
TRANSPORTATION EQUIP.	116	306							352
ELECTRICAL PRODUCTS									
NON-METALLIC MINERAL	664	16						1598	2278
PETROLEUM	60816							904	61720
CHEMICAL	63720	24618		26790				137078	382206
MISCELLANEOUS MANU - FACTURERS	37								37
MINERAL FUELS	4							478731	478735
QUARRIES AND SAND PITS									
TOTAL	254622	33415	4356	27050	-	-	520	722781	1024748

TABLE V111 - 20

WATER RECIRCULATION BY MAJOR FIRMS
SELECTED THREE-DIGIT INDUSTRIES, BY URBAN CENTER
ALBERTA, 1972

(Acre - Feet)

INDUSTRY	URBAN CENTER								TOTAL
	EDMONTON	CALGARY	LETHBRIDGE	MEDICINE HAT	GRANDE PRAIRIE	PEACE RIVER	RED DEER	OTHER	
COAL MINES	4							3782	3786
NATURAL GAS								474949	474949
OIL WELLS									
MEAT AND POULTRY	8240	1520	505				10		10335
FRUIT AND VEGETABLE									
DAIRY PRODUCTS	30	308		36			510	305	1189
FLOUR AND BREAKFAST CEREAL PRODUCTS									
FEED INDUSTRY	116	6							122
BAKERY PRODUCTS									
MISCELLANEOUS FOOD			3463					8813	12276
BEVERAGE	1580	5298	222						7100
CLAY PRODUCTS									
CEMENT	369								369
CONCRETE	3	16							19
READY MIX								14	14
GLASS	292							809	1101
LIME								775	775
MISCELLANEOUS MANUFACTURING									
TOTAL	10634	7148	4250	36	-	-	520	489417	512035

TABLE V111 - 21

WATER RECIRCULATION BY MAJOR FIRM
TWO-DIGIT INDUSTRIES, BY RIVER BASIN
ALBERTA, 1972

(ACRE - FEET)

INDUSTRY	RIVER BASIN					TOTAL
	PEACE RIVER	ATHABASCA	NORTH SASK.	RED DEER	SOUTH SASK.	
FOOD AND BEVERAGE			10271	420	20331	31022
RUBBER AND PLASTICS PRODUCTS					226	226
LEATHER						
CLOTHING			3			3
WOOD INDUSTIRES			1330		55	1385
FURNITURE						
PAPER			8052		10	8062
PRINTING						
PRIMARY METAL			102801		1332	104133
METAL FABRICATING			2585			2585
MACHINERY						
TRANSPORTATION EQUIP.			46		306	352
ELECTRICAL PRODUCTS						
NON-METALLIC MINERAL	14		664		1600	2278
PETROLEUM			61720			61720
CHEMICAL			300798		51408	352200
MISCELLANEOUS MANU-FACUTRERS			37			37
MINERAL FUELS	54392	37630	8316	231161	147236	478735
QUARRIES AND SAND PITS						
TOTAL	54406	37630	496623	231581	222504	1042744

TABLE V111 - 22

WATER RECIRCULATION BY MAJOR FIRMS
SELECTED THREE-DIGIT INDUSTRIES, BY RIVER BASIN
ALBERTA, 1972

(ACRE - FEET)

INDUSTRY	RIVER BASIN					TOTAL
	PEACE RIVER	ATHABASCA	NORTH SASK.	RED DEER	SOUTH SASK.	
COAL MINES	3782				4	3786
NATURAL GAS	50610	37630	8316	231161	147232	474949
OIL WELLS						
MEAT AND POULTRY			8240	10	2085	10335
FRUIT AND VEGETABLE						
DAIRY PRODUCTS			435	410	344	1189
FLOUR AND BREAKFAST CEREAL PRODUCTS						
FEED INDUSTRY			116		6	122
BAKERY PRODUCTS						
MISCELLANEOUS FOOD					12276	12276
BEVERAGE			1480		5620	7100
CLAY PRODUCTS						
CEMENT			369			369
CONCRETE			3		16	19
READY MIX	14					14
GLASS			292		809	1101
LIME					775	775
MISCELLANEOUS MANUFACTURING						
TOTAL	54406	37630	19251	231581	169167	512035

TABLE V111 - 23

DEGREE OF RECIRCULATION OF WATER BY MAJOR FIRMS
TWO-DIGIT INDUSTRIES, BY URBAN CENTER
ALBERTA, 1972

(PER - CENT)

INDUSTRY	URBAN CENTER								TOTAL
	EDMONTON	CALGARY	LETHBRIDGE	MEDICINE HAT	GRANDE PRAIRIE	PEACE RIVER	RED DEER	OTHER	
FOOD AND BEVERAGE	64	50	64	4			37	65	58
RUBBER AND PLASTICS PRODUCTS				47					16
LEATHER									
CLOTHING	18								18
WOOD INDUSTRIES	96							47	85
FURNITURE									
PAPER	94	1							21
PRINTING									
PRIMARY METAL	97	79						97	96
MACHINERY									
TRANSPORTATION EQUIP	43	49							48
ELECTRICAL PRODUCTS									
NON-METALLIC MINERAL	46	1						27	35
PETROLEUM	89							80	35
CHEMICAL	93	33		91				95	83
MISCELLANEOUS MANU-FACTURERS	16								16
MINERAL FUELS	4							83	83
QUARRIES AND SAND PITS									
TOTAL	90	27	61	88			37	85	79

TABLE V111 - 24

DEGREE OF RECIRCULATION OF WATER BY MAJOR FIRMS

SELECTED THREE-DIGIT INDUSTRIES, BY URBAN CENTER

ALBERTA, 1972

(PER - CENT)

INDUSTRY	URBAN CENTER								TOTAL
	EDMONTON	CALGARY	LETHBRIDGE	MEDICINE HAT	GRANDE PRAIRIE	PEACE RIVER	RED DEER	OTHER	
COAL MINES	5							62	61
NATURAL GAS								92	92
OIL WELLS									
MEAT AND POULTRY	70	30	34				2		53
FRUIT AND VEGETABLE	67							49	45
DAIRY PRODUCTS									
FLOUR AND BREAKFAST CEREAL									
FEED INDUSTRY	17	50							17
BAKERY PRODUCTS									
MISCELLANEOUS FOOD			93					66	72
BEVERAGE	54	64	41						59
CLAY PRODUCTS									
CEMENT	46								22
CONCRETE	2	15							4
READY MIX								15	1
GLASS	70							97	88
LIME								66	66
MISCELLANEOUS MANUFACTURING									
TOTAL	61	43	61	3			37	82	80

TABLE V111 - 25

DEGREE OF RECIRCULATION OF WATER BY MAJOR FIRMS
TWO-DIGIT INDUSTIRES, BY RIVER BASIN
ALBERTA, 1972

(PER - CENT)

INDUSTRY	RIVER BASIN					TOTAL
	PEACE RIVER	ATHABASCA	NORTH SASK.	RED DEER	SOUTH SASK.	
FOOD AND BEVERAGE			63	32	57	58
RUBBER AND PLASTICS PRODUCTS					17	16
LEATHER						
CLOTHING			18			18
WOOD INDUSTIRES			96		46	85
FURNITURE						
PAPER			94		1	21
PRINTING						
PRIMARY METAL			96		79	96
METAL FABRICATING			98			94
MACHINERY						
TRANSPORTATION EQUIP.			43		49	48
ELECTRICAL PRODUCTS						
NON-METALLIC MINERAL	30		35		35	35
PETROLEUM			89			65
CHEMICAL			94		49	83
MISCELLANEOUS MANUFACTURERS			16			16
MINERAL FUELS	83	44	22	97	97	83
QUARRIES AND SAND PITS						
TOTAL	83	32	88	97	68	79

TABLE VIII - 26

DEGREE OF RECIRCULATION OF WATER BY MAJOR FIRMS
SELECTED THREE-DIGIT INDUSTRIES, BY RIVER BASIN
ALBERTA, 1972

(PER - CENT)

INDUSTRY	RIVER BASIN					TOTAL
	PEACE RIVER	ATHABASCA	NORTH SASK.	RED DEER	SOUTH SASK.	
COAL MINES	68				2	1
NATURAL GAS	88	59	93	98	97	92
OIL WELLS						
MEAT AND POULTRY			70	2	29	53
FRUIT AND VEGETABLE			45	36	37	45
DAIRY PRODUCTS						
FLOUR AND BREAKFAST CEREAL PRODUCTS						
FEED INDUSTRY			17		25	17
BAKERY PRODUCTS						
MISCELLANEOUS FOOD					72	72
BEVERAGE			54		61	59
CLAY PRODUCTS						
CEMENT			30			22
CONCRETE			2		5	4
READY MIX	30					1
GLASS			68		98	88
LIME					66	66
MISCELLANEOUS MANUFACTURING						
TOTAL	83	44	35	97	88	80

TABLE V111 - 27

WATER DISCHARGE BY MAJOR FIRMS
TWO DIGIT INDUSTRIES, BY URBAN CENTER
ALBERTA, 1972

(Acre - Feet)

INDUSTRY	URBAN CENTER								TOTAL
	EDMONTON	CALGARY	LETHBRIDGE	MEDICINE HAT	GRANDE PRAIRIE	PEACE RIVER	RED DEER	OTHER	
FOOD AND BEVERAGE	5584	6422	2126	707	51		879	5276	21045
RUBBER AND PLASTICS PRODUCTS		84		231					315
LEATHER	153								153
CLOTHING	13								13
WOOD INDUSTRIES	18				59			64	141
FURNITURE									
PAPER	480	774						25687	26941
PRINTING	60								60
PRIMARY METAL	231	301		3				1529	2064
METAL FABRICATING	21	90							111
MACHINERY									
TRANSPORTATION EQUIP.	46	300							346
ELECTRICAL PRODUCTS		300	10						310
NON-METALLIC MINERAL	185	1505	313	33	2	1	2	574	2615
PETROLEUM	5600	25686						16	31302
CHEMICAL	8456	50120		2110				5161	65,907
MISCELLANEOUS MANU-FACTURERS	172								172
MINERAL FUELS	63	600						23334	23997
QUARRIES AND SAND PITS	2	5			1			5	13
TOTAL	21024	86307	2449	3084	113	1	881	61646	175505

TABLE V111 - 28

WATER DISCHARGE BY MAJOR FIRMS
SELECTED THREE DIGIT INDUSTRIES, BY URBAN CENTER
ALBERTA, 1972

(ACRE - FEET)

INDUSTRY	URBAN CENTER								TOTAL
	EDMONTON	CALGARY	LETHBRIDGE	MEDICINE HAT	GRANDE PRAIRIE	PEACE RIVER	RED DEER	OTHER	
COAL MINES	63							1011	1074
NATURAL GAS		600						22323	22923
OIL WELLS									
MEAT AND POULTRY	3359	3400	1024	584	33		536		8936
FRUIT AND VEGETABLE			500					272	772
DAIRY PRODUCTS	336	444		18			300	100	1198
FLOUR AND BREAKFAST CEREAL PRODUCTS		30		5					35
FEED INDUSTRY	517	6	11				28		562
BAKERY PRODUCTS	72	22							94
MISCELLANEOUS FOOD			255					4445	4700
BEVERAGE	1300	2520	336	100	18		15	25	4314
CLAY PRODUCTS	2		2	32				21	57
CEMENT	29							144	173
CONCRETE PRODUCTS	70	21	310						401
READY MIX	3	1484	1	1	2	1	2	85	1579
GLASS	81							13	94
LIME								194	194
MISCELLANEOUS MANUFACTURING									
TOTAL	5832	8527	2439	740	53	1	881	28633	47106

TABLE V111 - 29

WATER DISCHARGE BY MAJOR FIRMS

TWO DIGIT INDUSTRIES, BY RIVER BASIN

ALBERTA, 1972

(ACRE - FEET)

INDUSTRY	RURAL BASIN					TOTAL
	PEACE RIVER	ATHABASCA	NORTH SASKATCHEWAN	RED DEER	SOUTH SASKATCHEWAN	
QUARRIES AND SNAD PITS	1		5		7	13
FOOD AND BEVERAGE	51		5689	902	14403	21045
RUBBER AND PLASTICS PRODUCTS					315	315
LEATHER			153			153
CLOTHING			13			13
WOOD INDUSTRIES	59		18		64	141
FURNITURE						
PAPER		25711	456		774	26941
PRINTING					60	60
PRIMARY METAL			1760		304	2064
METAL FABRICATING			21		90	111
MACHINERY						
TRANSPORTATION EQUIP.			46		300	346
ELECTRICAL PRODUCTS					310	310
NON-METALLIC MINERAL	4		224	4	2383	2615
PETROLEUM			5670	32	25600	31302
CHEMICAL			13104		52803	65907
MISCELLANEOUS MANU- FACTURERS			172			172
MINERAL FUELS	5124	14575	310	2071	1917	23897
TOTAL	5239	40286	27641	3009	99330	175505

TABLE V111 - 30

WATER DISCHARGE, BY MAJOR FIRMS
SELECTED THREE DIGIT INDUSTRIES, BY RIVER BASIN
ALBERTA, 1972

(ACRE - FEET)

INDUSTRY	RURAL BASIN					
	Peace River	Athabasca	North Sask.	Red Deer	South Sask.	TOTAL
COAL MINES	884			1	189	1074
NATURAL GAS	4240	14575	310	2070	1728	22923
OIL WELLS						
MEAT AND POULTRY	33		3359	536	5008	8936
FRUIT AND VEGETABLE					772	772
DAIRY PRODUCTS			436	300	462	1198
FLOUR AND BREAKFAST CEREAL PRODUCTS			5		30	35
FEED INDUSTRY			517	28	17	562
BAKERY PRODUCTS			72		22	94
MISCELLANEOUS FOOD					4700	4700
BEVERAGE	18		1251	18	3027	4314
CLAY PRODUCTS			2		55	57
CEMENT			58		115	173
CONCRETE PRODUCTS			70		331	401
READY MIX	4		8	4	1563	1579
GLASS			86		8	94
LIME					194	194
MISCELLANEOUS MANUFACTURING						
TOTAL	5179	14575	6209	2957	19186	47106

TABLE V111 - 31

WASTE-WATER TREATMENT BY MAJOR FIRMS
TWO-DIGIT INDUSTRIES BY URBAN CENTER
ALBERTA, 1972

(Acre - Feet)

INDUSTRY	URBAN CENTER								TOTAL
	EDMONTON	CALGARY	LETHBRIDGE	MEDICINE HAT	GRANDE PRAIRIE	PEACE RIVER	RED DEER	OTHER	
FOOD AND BEVERAGE	1840	3235	779	162	30		310	4086	10492
RUBBER AND PLASTICS PRODUCTS				231					231
LEATHER									
CLOTHING									
WOOD INDUSTIRES	4								4
FURNITURE									
PAPER	313	5						25713	26031
PRINTING									
PRIMARY METAL									
METAL FABRICATING									
MACHINERY									
TRANSPORTATION EQUIP.	7	14							21
ELECTRICAL PRODUCTS		182							182
NON-METALLIC MINERAL		1557	253						1810
PETROLEUM	4512	7121						92	11725
CHEMICAL		97		2110				2860	5067
MISCELLANEOUS MANUFACTURERS									
MINERAL FUELS		154						14020	14174
QUARRIES AND SAND PITS									
TOTAL	6676	12415	1032	2503	30	-	310	46771	69737

TABLE VIII - 32

WASTE-WATER TREATMENT BY MAJOR FIRMS
SELECTED THREE-DIGIT INDUSTRIES, BY RIVER BASIN
ALBERTA, 1972

(Acre - Feet)

INDUSTRY	URBAN CENTER								
	EDMONTON	CALGARY	LETHBRIDGE	MEDICINE HAT	GRANDE PRAIRIE	PEACE RIVER	RED DEER	OTHER	TOTAL
COAL MINES								2	2
NATURAL GAS		154						14018	14172
OIL WELLS									
MEAT AND POULTRY	1840	3285	480	162	30		307		6104
FRUIT AND VEGERABLE			287					17	304
DAIRY PRODUCTS IND.									
FLOUR AND BREAKFAST CEREAL PRODUCTS									
FEED INDUSTRY									
BAKERY PRODUCTS									
MISCELLANEOUS FOOD			12					4072	4084
BEVERAGE									
CLAY PRODUCTS									
CEMENT									
CONCRETE PRODUCTS		1	155						156
READY MIX		1556						1	1557
GLASS									
LIME								97	97
MISCELLANEOUS MANUFACTURING									
TOTAL	1840	4996	934	162	30	–	307	18207	26476

TABLE V111 - 33

WASTE-WATER TREATMENT BY MAJOR FIRMS
TWO-DIGIT INDUSTRIES, BY RIVER BASIN
ALBERTA, 1972

(ACRE - FEET)

INDUSTRY	RIVER BASIN					
	PEACE RIVER	ATHABASCA	NORTH SASK.	RED DEER	SOUTH SASK.	TOTAL
FOOD AND BEVERAGE	30		1840	310	8312	10492
RUBBER AND PLASTICS PRODUCTS					231	231
LEATHER						
CLOTHING						
WOOD INDUSTRIES			4			4
FURNITURE						
PAPER		25711	320			26031
PRINTING						
PRIMARY METAL						
METAL FABRICATING						
MACHINERY						
TRANSPORTATION EQUIP.			7		14	21
ELECTRICAL PRODUCTS					182	182
NON-METALLIC MINERAL		1			1809	1810
PETROLEUM			4572	32	7121	11725
CHEMICAL			2859		2208	5067
MISCELLANEOUS MANUFACTURERS						
MINERAL FUELS	828	11544	162	854	786	14174
QUARRIES AND SAND PITS						
TOTAL	859	37255	9764	1196	20663	69737

TABLE V111 - 34.

WASTE-WATER TREATMENT BY MAJOR FIRMS
SELECTED THREE-DIGIT INDUSTRIES, BY RIVER BASIN
ALBERTA, 1972

(ACRE - FEET)

INDUSTRY	RIVER BASIN					TOTAL
	Peace River	Athabasca	North Sask.	Red Deer	South Sask.	
COAL MINES					2	2
NATURAL GAS	828	11544	162	854	784	14172
OIL WELLS						
MEAT AND POULTRY	30		1840	310	3924	6104
FRUIT AND VEGETABLE					304	304
DAIRY PRODUCTS						
FLOUR AND BREAKFAST CEREAL PRODUCTS						
FEED INDUSTRY						
BAKERY PRODUCTS						
MISCELLANEOUS FOOD					4084	4084
BEVERAGE						
CLAY PRODUCTS						
CEMENT						
CONCRETE					156	156
READY MIX	1				1556	1557
GLASS						
LIME					97	97
MISCELLANEOUS MANUFACTURING						
TOTAL	859	11544	2002	1164	10907	26476

TABLE V111 - 35

CONSUMPTIVE USE OF WATER BY MAJOR FIRMS
TWO-DIGIT INDUSTRIES, BY URBAN CENTER
ALBERTA, 1972

(Acre - Feet)

INDUSTRY	URBAN CENTER								TOTAL
	EDMONTON	CALGARY	LETHBRIDGE	MEDICINE HAT	GRANDE PRAIRIE	PEACE RIVER	RED DEER	OTHER	
FOOD AND BEVERAGE	389	584	312	118	17	11	16	171	1618
RUBBER AND PLASTICS PRODUCTS	39	772		18					829
LEATHER									
CLOTHING	1								1
WOOD INDUSTRIES	34	13			1				48
FURNITURE		6							6
PAPER		1						3565	3566
PRINTING									
PRIMARY METAL	12	49		3				2419	2478
METAL FABRICATING	42								42
MACHINERY		85							85
TRANS. EQUIP.	16	22							38
ELECTRICAL PRODUCTS									
NON-METALLIC MINERAL	583	271	15	14	3			955	1841
PETROLEUM	1856							213	2069
CHEMICAL	3074	5		527				1599	5205
MISCELLANEOUS MANUFACTURERS	18								18
MINERAL FUELS	21	10						76984	77015
QUARRIES AND SAND PITS									
TOTAL	6085	1818	327	680	21	11	16	85901	94859

TABLE VIII - 36

CONSUMPTIVE USE OF WATER BY MAJOR FIRMS
SELECTED THREE-DIGIT INDUSTRIES BY URBAN CENTER
ALBERTA, 1972

(ACRE - FEET)

INDUSTRY	URBAN CENTER								TOTAL
	EDMONTON	CALGARY	LETHBRIDGE	MEDICINE HAT	GRANDE PRAIRIE	PEACE RIVER	RED DEER	OTHER	
COAL MINES	21							921	942
NATURAL GAS		10						18894	18904
OIL WELLS								57169	57169
MEAT AND POULTRY	217	72	74	36			6		405
FRUIT AND VEGETABLE	15		4					144	163
DAIRY PRODUCTS	84	4	110	29	11	11	6	4	259
FLOUR AND BREAKFAST CEREAL PRODUCTS				3				3	6
FEED INDUSTRY	34						1		35
BAKERY PRODUCTS									
MISCELLANEOUS FOOD	11	76						16	103
BEVERAGE	28	432	124	50	6		3	4	647
CLAY PRODUCTS				12				8	20
CEMENT	406							723	1129
CONCRETE	105	70							175
READY MIX	27	137	5	2	3			7	181
GLASS	45							15	60
LIME			10					202	212
MISCELLANEOUS MANUFACTURING		64							64
TOTAL	993	865	327	132	20	11	16	78110	80474

TABLE V111 - 37

CONSUMPTIVE USE OF WATER BY MAJOR FIRMS
TWO-DIGIT INDUSTRIES, BY RIVER BASIN
ALBERTA, 1972

(ACRE - FEET)

INDUSTRY	RIVER BASIN					
	PEACE RIVER	ATHABASCA	NORTH SASK.	RED DEER	SOUTH SASK.	TOTAL
FOOD AND BEVERAGE	28		374	20	1196	1618
RUBBER AND PLASTICS PRODUCTS			39		790	829
LEATHER						
CLOTHING			1			1
WOOD INDUSTRIES	1	11	36			48
FURNITURE					6	6
PAPER		3506	60			3566
PRINTING						
PRIMARY METAL			2430		48	2478
METAL FABRICATING			42			42
MACHINERY					85	85
TRANS. EQUIP.			16		22	38
ELECTRICAL PRODUCTS						
NON-METALLIC MINERAL	28		1003	4	806	1841
PETROLEUM			1970	13	86	2069
CHEMICAL			5184		21	5205
MISCELLANEOUS MANU-FACTURERS			18			18
MINERAL FUELS	5892	33922	28910	4914	3377	77015
QUARRIES AND SAND PITS						
TOTAL	5949	37439	40083	4951	6437	94857

TABLE V111 - 38

CONSUMPTIVE USE OF WATER BY MAJOR FIRMS
SELECTED THREE-DIGIT INDUSTRIES, BY RIVER BASIN
ALBERTA, 1972

(ACRE - FEET)

INDUSTRY	River Basin					
	PEACE RIVER	ATHABASCA	NORTH SASK.	RED DEER	SOUTH SASK.	TOTAL
COAL MINES	942					942
NATURAL GAS	2660	11682	350	2070	2142	18904
OIL WELLS	2290	22240	28560	2844	1235	57169
MEAT AND POULTRY			211		194	405
FRUIT AND VEGETABLE			15		148	163
DAIRY PRODUCTS	22		103	20	114	259
FLOUR AND BREAKFAST CEREAL					6	6
FEED INDUSTRY			34		1	35
BAKERY PRODUCTS						
MISCELLANEOUS FOOD		11			92	103
BEVERAGE	6				641	647
CLAY PRODUCTS					20	20
CEMENT			812		317	1129
CONCRETE			105		70	175
READY MIX	28		32	4	117	181
GLASS			54		6	60
LIME					212	212
MISCELLANEOUS MANUFACTURING					64	64
TOTAL	5948	33922	30922	4938	5379	80474

Appendix IX

Water Rates

Calgary, Alberta

1971

THE CITY OF CALGARY

WATER RATES
MARCH 1st, 1971

General Service Metered Water Rate

First	5,000	.........68¢ per 1,000 gals.
Next	5,000	.........62¢ per 1,000 gals.
Next	20,000	.........55¢ per 1,000 gals.
Next	30,000	.........45¢ per 1,000 gals.
Next	90,000	.........31¢ per 1,000 gals.
Next	350,000	.........28¢ per 1,000 gals.
All over	500,000	.........23¢ per 1,000 gals.

Minimum Charge on Meters

5/8 inch meter(incl. 1/2in. serv. line) per month ..	$ 3.40
3/4 inch meter, per month	3.77
1 inch meter, per month	4.47
1 1/2 inch meter, per month	8.47
2 inch meter, per month	11.86
3 inch meter, per month	11.86
4 inch meter, per month	25.41
6 inch meter, per month	42.35
8 inch meter, per month	54.21
10 inch meter, per month	66.07